# Some considerations for the management of coastal lagoon and estuarine fisheries

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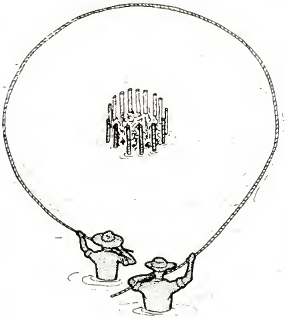

FOOD
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# Some considerations for the management of coastal lagoon and estuarine fisheries

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## PREPARATION OF THIS PAPER

This is one of a series of reports periodically produced by the FAO Fishery Resources and Environment Division to help to meet the needs of fishery workers of Member Countries for syntheses of information in the fields of applied fishery research and fishery management.

The objective of the present report is to provide a synthesis of information on the management of capture fisheries in coastal lagoons and estuaries in developing countries. The report provides an overview of fishery management options available by describing various regulatory and non-regulatory fishery management combinations which have been applied to coastal lagoons and estuaries in a number of differing technical, economic, and social situations.

The report also attempts to anticipate future needs for the management of capture fisheries in coastal lagoons and estuaries by illustrating how these fisheries interact, compete, or conflict with rapidly developing aquaculture, recreational fisheries, and with the nearshore and offshore fisheries.

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## ABSTRACT

Management of artisanal fisheries in coastal lagoons and estuaries is treated in three broad categories -- regulatory management, non-regulatory management, and interactions between fisheries or fishery interests.

Regulation of artisanal fisheries in coastal lagoons and estuaries by government authority is hampered for several reasons. Technical and financial constraints on government severely limit enforcement capabilities. Socio-economic considerations, chiefly the lack of alternative employment opportunities for fishermen, preclude the adoption of many of the classical regulatory management techniques. As a means to complement or supplement management by central government authority, revitalization of local traditional authority is advocated.

Non-regulatory management, the application of methods which increase capture and culture fishery potential through manipulation of the environment, is illustrated by various kinds of hydraulic engineering, predator control, stocking, artificial nursery areas, and brush-park fisheries.

Interactions between fisheries or fishery interests is treated at several levels. Considered are competition between groups of fishermen of different ethnic and economic backgrounds, interactions between artisanal capture fisheries and aquaculture, and competition between artisanal fisheries of coastal lagoons and estuaries and offshore industrial fisheries which fish the same stocks.

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# SOME CONSIDERATIONS FOR THE MANAGEMENT OF COASTAL LAGOON AND ESTUARINE FISHERIES

## 1. INTRODUCTION

### 1.1 Background and Objectives

Relative to marine and inland waters, the fisheries of coastal lagoons and estuaries in developing countries have received little attention up to the present. A number of factors have contributed to this situation. One is that coastal lagoons and estuaries do not easily fit into the usual "Marine" and "Inland" categories under which most national fishery departments are presently organized. Secondly, the fisheries of coastal lagoons and estuaries are often based on multi-species resources which vary widely in availability in time and space -- marine "visitors", euryhaline "permanent residents", freshwater "visitors", and migratory catadromous and anadromous "transients". This stock complexity contributes to the difficulty of resource evaluation, and hence to the formulation of management programmes. An additional reason for the relative neglect of lagoon and estuarine fisheries in developing countries is that they are in the main small-scale and of an artisanal or subsistence character. The fisheries are usually operated by individuals or family groups using traditional labour-intensive fishing methods from small craft. Fishermen and fishing communities may be widely dispersed, and much of the catch may be sold informally through local channels with only the most valuable fishery products entering national statistical tables, and then usually without mention of the lagoon or estuarine origin of the product.

Some of the same characteristics which make coastal lagoon and estuarine fisheries difficult to manage also make them relatively valuable in their own right, or important for their potential or actual effect on other fisheries. Among these are that some of the same stocks which are fished at varying levels of intensity in lagoons and estuaries also support offshore marine industrial fisheries or nearshore coastal artisanal fisheries, for example, for shrimp. Biologically, estuaries and lagoons provide nursery areas for fishes and crustaceans which spend the remainder of their life cycles at sea, or in fresh waters. Further, lagoons and estuaries provide avenues of entry and exit for migration of anadromous and catadromous fishes. From the socio-economic viewpoint the small-scale, labour-intensive character of the fisheries provides income, employment, and protein self-sufficiency for coastal fishing peoples while the surplus catch contributes to the food supply at nearby urban centres. In some situations where high-value resources are exploited for export, such as shrimps, crabs, and oysters, the lagoon and estuarine fisheries also contribute to the national economy by providing a source of foreign exchange. Finally, estuaries and lagoons of developing countries increasingly provide opportunities for a rapidly developing aquaculture industry and for recreational fisheries. Clearly, the importance and complexity of coastal lagoon and estuarine fisheries demand that they should be well-managed if their fishery resources are to be exploited in an optimum manner and if the maximum of social and economic benefits are to be realized from their resources.

In this context, this report is aimed at filling a need for information on the management of coastal lagoon and estuarine capture fisheries in developing countries. In part, the report serves to indicate the status of fishery management activities in coastal lagoons and estuaries. At the same time, using examples drawn from a number of fisheries in differing technological, economic and social situations, it provides an overview of the scope of management activities available. An additional feature is that an attempt has been made to anticipate fishery interactions and conflicts which may become important management considerations in the near future.

The present report confines itself rather rigidly to the management of fisheries per se; however, a subsequent report is planned which will deal with the broader aspects of fishery management in coastal lagoons and estuaries -- management of fisheries in relation to environmental alterations and perturbations, and fisheries within the multiple-use context of lagoons and estuaries. Likewise, another report now in preparation, will be a compilation of information on fishery yields and yield prediction in coastal lagoon and estuaries.

The general approach used in this report is to illustrate management problems, and to examine management solutions which have been applied or proposed by using examples taken from a number of

lagoon and estuarine fisheries. In this manner considered first are the classical approaches to the management of lagoon and estuarine fisheries -- regulation of entry, restrictions on fishing gears, on locations, and on fishing seasons. Also included is the possibility of revitalizing traditional fishery management methods. Then, the focus turns to various possibilities for the management of lagoon and estuarine fisheries through non-regulatory methods, those which increase fishery productivity -- hydraulic engineering, predator control, stocking, and brush-park fisheries. Finally, from a different perspective, management of lagoon and estuarine fisheries is considered from the viewpoint of actual or potential interactions, competition or conflicts, with other kinds of fisheries -- ethnic and socio-economic interactions, potential conflicts with aquaculture, and interactions with marine nearshore and offshore fisheries.

## 2. REGULATORY MANAGEMENT OF LAGOON AND ESTUARINE FISHERIES

### 2.1 Lagoon and Estuarine Fishing Practices which Require Regulation

Blocking of lagoon/sea access channels by fixed or movable fishing gears appears to be a universal problem where lagoon fisheries are intensive, particularly when practised indiscriminately on outward or inward bound migrations for reproduction and on inward bound migrations of larval shrimp or fishes. Examples of this problem are known in the Chilka (Jhingran and Natarajan, 1969) and Pulicat (Menon and Raman, 1977) lagoons in India. In the latter, fixed stake nets are said to "choke" the lagoon mouth during high tide and to filter out prawns and finfishes, irrespective of size. In the former, concern has been expressed because of interference with the seaward spawning migrations of Mugil and Lates. Fishing close to the lagoon mouths on inward and outward migrations has also been recognized as inimical to the lagoon finfish fishery in the Laguna Madre de Tamaulipas (Mexico) by Meza (1980) and to the shrimp fishery there by Martinez Mata (1980). Numerous fish weirs completely block the channel interconnecting the lagoons of the Inharrime River (Mozambique) with the sea. Abundance of fishes of marine origin in the system is apparently inversely related to the number of weirs which the fish must pass through on inward migrations (Matthes, 1981).

The locations of various kinds of fishing gears used mainly for shrimp fishing in various connecting water courses of the Lagōa de Araruama, Brazil, have been plotted by Slack-Smith et al. (1977) (Fig.1). Here, too, blockage of channels by gears is recognized as one of the factors which has caused a decrease in shrimp yields in recent years. One trap so tightly blocked waterflow that there was a 10 cm difference in water level between the lagoon and the channel, a condition which would prejudice the entrance of post-larval shrimp to the lagoon which takes place throughout the year.

Other problems identified in relation to the operation of fishing gears in lagoons are fishing in parts of the lagoon known to be nursery areas where juvenile shrimps are concentrated (Slack-Smith et al., 1977: Martinez Mata, 1980). This practice is usually combined with the use of small mesh sizes (Barrera Huerta, 1976). Meza (1980) also notes that the use of active gears which are fished along the lagoon bottom for finfishes in Laguna Madre de Tamaulipas leaves paths bare of vegetation and also destroys natural oysters beds.

### 2.2 Regulatory Management Methods

Among the management solutions proposed by Slack-Smith et al. (1977) to reduce the overfishing of shrimp by the artisanal fisheries of Lagōa de Araruama was the removal of fishing gears which completely blocked the access channels to the lagoon (those allowing some area of free passage could remain as long as their numbers would not be increased). Matthes (1981) proposed a similar solution for the blockage of fish migrations in the Inharrime lagoon system. A trap configuration was designed that permits passage of fishes on inward and outward migrations as a replacement for the weirs (Fig.2).

Additional management measures advocated by Slack-Smith et al. (1977) were the registration of the some 1 000 fishermen and their gears. Based on this registration no new fishermen or gears were to be permitted to enter the fishery. Also recommended was a restriction which would limit the use of some active gears to deeper areas of the lagoon.

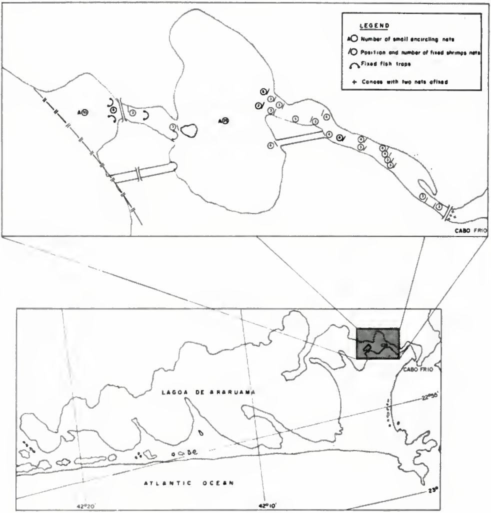



Fig. 1. Locations of various kinds of fishing gears in the connecting channels of the Lagõa de Araruama, Brazil (from Slack-Smith et al., 1977)

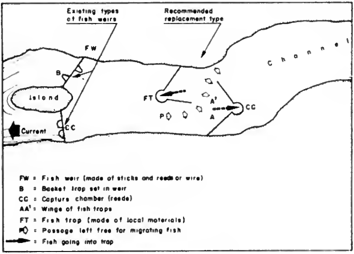



Fig. 2. Existing fish weirs, and recommended replacement by fish traps with capture chambers which permit migrations (from Matthes, 1981)

Limitation of mesh sizes for shrimp fishing was not recommended because of a lack of information on gear selectivity and also because an earlier attempt to enforce a minimum size limit for shrimp caused a decline in fishermen's income to such an extent that their economic survival was threatened. Further, gears using meshes smaller than those than prevalent would be made inoperable because of clogging by the abundant plant material of the lagoon.

In Bardawil lagoon along the Mediterranean in Egypt, amelioration of a hypersalinity condition in 1970, through maintaining continuous connections with the sea led to an increase in stocks but also stimulated a rapid expansion of the fishery. This led to overexploitation of the valuable Sparus aurata resources of the lagoon (Ben-Tuvia, 1979). In the late 1960's the fishery was largely subsistence-oriented and fishing was from 50 sailboats. By 1972, the number of boats had increased to 179, of which 68 were motor-powered (Pisanty, 1980). Cotton nets were replaced by synthetic fibres, and net numbers and lengths increased. Subsequent biological investigations showed an urgent need for regulation of the fishery and a number of fishery management measures were adopted. These included mesh-size regulation, establishment of a minimum legal length, a closed season to protect the seaward spawning migration of Sparus and also to provide protection for the non-migrating younger year class which remains in the lagoon over winter (Ben-Tuvia, 1979). Additional fishery management measures adopted were licensing of fishermen, boats, and gears, a permit system regulating fishing effort on a rotational basis, and restrictions on gear dimensions (Pisanty, 1980).

As a result of the hydraulic and fishery management programmes the yield from the lagoon was doubled and the value of the fishery was increased tenfold over the period 1968-78 (Pisanty, 1980).

It is noteworthy that the tax of about 15 percent imposed on the gross value of the catch was ample to support the hydraulic management of the lagoon as well as the cost of research, administration and management of the lagoon fishery.

Another factor which must have contributed to the success of the fishery, in addition to the comprehensive fishery management programme itself, though not mentioned specifically by Ben-Tuvia (1979) or Pisanty (1980), is that the lagoon is somewhat isolated and therefore management regulations were more easily enforced. Additionally, management measures were formulated and imposed before the fishery got out of hand, and the management measures selected proved to be quite appropriate from the outset.

On Lake Borullus, one of five Nile Delta coastal lagoons in Egypt, regulations on the fishery include prohibition of fishing in the area of the lake-sea connection, minimum mesh sizes on gears, restrictions on some gear types and speed limit on trawling. However, Libosvarsky, Lusk and El-Sedfy (1972) state that these regulations are not adhered to, presumably for lack of enforcement.

Chilka Lake, in India, varying in surface area from 96 500 to 116 500 $hm^2$, supports an incredibly complex conglomeration of fishing gears in the broad types: nets, traps, and "janos" (impoundements). Jhingran and Natarajan (1969) list 13 different kinds of nets in use there which are variations of drag, gill, and castnets. Netting is carried out both on leased grounds (exclusive fishing rights) and in other unleased areas on a fee basis. There are 112 jano impoundment fisheries which are leased out and which total 13 550 $hm^2$ (13 percent of average lagoon surface area) and 67 leased prawn fisheries (traps). A map of the entire lagoon and of several sections of the lagoon at a larger scale (Fig.3) provide an idea of the density of fishing gears used there in leased areas.

The fishery is based on ten principal commercially important finfishes and two species of shrimps, as well as crabs. The resources are somewhat overexploited as suggested by the small size of individuals, their young age at capture, and by relatively high fishing mortality rates.

Among the management measures suggested for this fishery by Jhingran and Natarajan (1969) were limiting fishing on the seaward reproductive migration of mullets and the banning of fishing on lagoonward migrating mullet fry, both of which occur in the narrow channel linking the lagoon to the sea.

Inside the lagoon, Jhingran and Natarajan (1969) suggested that minimum sizes be set for the commercially important finfishes with those of less than minimum size returned to the lagoon alive. Minimum size restrictions would be enforced through monitoring at markets. With such a diversity of gear types, minimum mesh size restrictions were considered unworkable. Other management measures recommended were induced breeding of mullet for lake stocking and for culture, use of shallow portions of the lake for aquaculture with some of the seed to be supplied from the lake, thinning of prawn traps located in areas affecting fish and prawn migration routes, and hydraulic engineering to maintain the lagoon/sea connection.

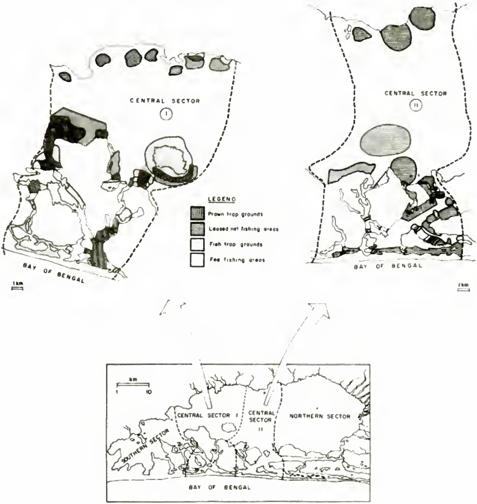



Fig. 3. The distribution of various kinds of fishing grounds and fishing areas in Chilka Lake, India (adapted from Jhingran and Natarajan, 1969)

A management technique favoured in Mexican lagoon shrimp fisheries is the closed season, "veda", which is timed to protect shrimp during their period of rapid growth in lagoons, before their seaward migration for reproduction. Considerable research has been exerted to rationalize the timing and duration of the veda (Castro Melendez and Santiago Villalobos, 1976; Barrera Huerta, 1976, for example) and to properly phase the operation of shrimp trapping devices ("tapos", "atravesadas") with the seaward migration of shrimp (Reyna Cabrera, 1976; Gezan Soto, 1976). However, facilitating the entry to the lagoons of shrimp post-larvae, eggs and juveniles of finfishes, and crab larvae while simultaneously avoiding excess escapement of seaward migrating shrimp of fishable size (Barrera Huerta, 1976) and without excess loss of water from the lagoon (Edwards, 1978a) have remained a problem. For example, Barrera Huerta (1976) mentions that in lagoon systems of Oaxaca (Pacific Coast), operation of the structure favouring the first pulse of lagoonward migrating shrimp would have it open for entrance of post-larvae until the end of June and closed thereafter. However, in September there occurs another pulse of lagoonward migration of shrimp post-larvae which coincides with a seaward migration of harvestable-sized shrimp from the lagoon. Edwards (1978a) has proposed a scheme whereby two tapos would be operated in tandem in the same channel, with alternating openings and closings. This would permit both access by in-migrating shrimp post-larvae and the capture of out-migrants. However, he observes that such management would require liaison between the fishing cooperatives owning each of the tapos.

An artisanal fishery for Penaeus duorarum developed on the Casamance Estuary (Senegal) with the stimulus of the installation of a shrimp processing factory there in 1960. Historically, the development of the shrimp fishery had been marked by a more or less regular increase in shrimp yield and in fishing effort up until 1968. However, from the period 1968 through 1976 effort increased progressively while catch varied. In the period 1974-76 the catch decreased by about one-third, causing official concern that the resource was endangered.

The problem was believed to be that the increase in fishing effort had been accompanied by an extension of shrimp fishing into areas not traditionally fished beforehand, and that these newly-fished areas harboured small-sized shrimp which had previously not been included in the fishery. Thus, it was thought that the decrease in catch was caused by an overexploitation of juvenile shrimp.

In line with this hypothesis, a number of regulatory management measures were adopted in 1977. These included setting aside mangrove creeks as closed areas, limiting shrimp fishing to a well-defined portion of the main channel of the Casamance River, a prohibition on the use of drag-seines along the shoreline, and the setting of a minimum mesh size for the gears which were not restricted.

However, Le Reste (1980, and MS), in a study subsequent to the institution of the regulations, has found that annual shrimp yields in the estuary were governed much more by historical variations in salinity than by the effects of the fishery on shrimp resources. In particular, the results of the analysis showed that the timing of the outward migration of shrimp from the estuary, and most importantly for the fishery, the size at which shrimp migrate, are controlled by annual variations of salinity. Furthermore, salinity variations affect the spatial distribution of shrimp within the estuary.

Given that the present objective of management of the shrimp fishery in the Casamance estuary is to maximize the value of the catch which, in turn, implies that management be directed toward a strategy which maximizes the quantity of the large-sized, most valuable shrimp, Le Reste (MS) advocates that the minimum mesh-size regulations should remain in force. However, with regard to the closed areas, he notes that biological responses of shrimp to annual changes in salinity will be reflected in varying shrimp distribution patterns within the estuary. Therefore, it is not realistic to expect that large-sized shrimp will always be found within the estuarine areas now open to fishing, and he recommends some flexibility in the legislation governing the geographic limits of the closed areas along with implementation of a system to monitor shrimp fishing.

In a somewhat different perspective than the direct regulatory techniques that have been mentioned above is an "administrative" approach to the management of small-scale fisheries through the creation of fishing franchises. The franchise is thus a vehicle to moderate or remove the condition of common property (Christy, in prep.). By granting exclusive rights for the exploitation of fishery resources there is an incentive to self-regulate and to self-enforce to maximize resource benefits by the organization granted the franchise.

Leasing of estuarine and lagoon fishing grounds appears to be common practice in India as in Chilka Lake (Jhingran and Natarajan, 1969) and the Mahanadi estuarine system (Shetty, Chakraborty and Bhattacharya, 1965), but the extent to which this is used as a management tool is unclear from the literature available, although the impression is given that leasing is viewed predominantly as a source of government revenue.

Shetty, Chakraborty and Bhattacharya (1965), in connection with the fisheries of the Mahanadi estuarine system (Orissa), mention exploitation of the fishermen through the leasing system by the "Mokaddams" (landlords) in former times during which fishermen had to give over one-half of the value of their catches for fishing rights. Subsequently, the allocation of fishing rights through leases was brought under government control; however, at least in some areas leases have been taken up by the wealthy "landlords" once more and fishermen are once again forced to pay dearly for fishing rights.

The leasing system of the Mahanadi estuary seems to be similar to that presently practised for inland water fisheries in Bangladesh. In former times, on the floodplain lake/river systems wealthy landlords leased fishing rights directly to the fishermen for periods of up to 20 or 30 years. Under these conditions there was considerable incentive for the fishermen to manage exploitation to ensure a high and sustainable output year after year. Care was taken to preserve nursery areas, and channels and dikes were maintained for hydraulic control to benefit fish production. However, with the breaking up of large estates through agrarian reform after independence, leasing of fishing rights came under the public domain. Leases for fishing rights were shortened to one, two, or three years. As a result, the exploitation strategy changed toward extracting the maximum in the shortest possible time and catches decreased, as well as revenues to government (Kapetksy, unpublished).

Given the proper set of conditions, leasing of fishing grounds can be a powerful fishery management tool which also can provide considerable socio-economic benefits for fishermen while reducing somewhat the costs of management. Among the conditions which have to be met are: (1) relatively long-term leases as an incentive toward rational exploitation; (2) geographically well-defined limits on the lease (lagoon, arm of an estuary); (3) a fishery preferably based mainly on stocks which complete their life cycle within the leased area, or provision of areas closed to fishing or closed seasons so that migratory fishes have an opportunity to complete their life cycles, and so that each leased fishing ground has a more or less equal opportunity of receiving migratory juveniles and adults; and (4) a strong, uncorruptable local or central government infrastructure to administer the leasing system for the benefit of fishermen.

## 2.3 Some Perspectives on the Regulatory Management of Coastal Lagoon and Estuarine Fisheries

The examples presented above have illustrated a variety of perceived needs and some applications of different kinds and combinations of regulatory management techniques for a number of coastal lagoon and estuarine fisheries.

This brief perspective has been added to call attention to some additional and important aspects of the management of coastal lagoon and estuarine fisheries which have not been explicitly covered in these examples.

### 2.3.1 Objectives of regulatory management

Implicit in nearly all of the examples is that the objectives of regulatory management is to ensure maximum yield or maximum economic value of the yield. In fact, in the great majority of coastal lagoon and estuarine fisheries of developing countries, socio-economic conditions -- mainly underemployment and lack of alternative employment opportunities for fisherman -- dictate that fisheries have to be managed in such a way as to ensure maximum employment, even if this objective results in marginal economic benefits to the individual fishermen and even if total fishery output suffers. Therefore, one of the most potent of regulatory management tools, limitation of entry, either in terms of direct regulation of total numbers of fishermen, indirect regulation of entry by gear type, or by closed seasons, may not be acceptable in many coastal lagoon and estuarine fishery situations except where fishermen have other employment opportunities, or where these opportunities can be created.

2.3.2 Some difficulties in the formulation and implementation of regulatory management methods

In addition to socio-economic situations which militate against the limitation of entry to coastal lagoon and estuarine fisheries as a means of management, there are other factors which also limit management options. In terms of the formulation of appropriate management policy and strategy, lack of sufficient information such as on basic fish biology, yield, effort, economic and environmental data, may constrain the design of management programmes or result in the application of inappropriate management regulations. Le Reste's (1980 and MS) studies of the Casamance estuary shrimp fishery cited in the previous section, provide a case in point of the establishment of a set of management regulations based on insufficient or inaccurate information.

As a result of the same lack of information almost invariably the fishery situation has already gotten out of hand before the need for regulatory management is officially recognized, and therefore the implementation of an appropriate management programme under these circumstances is all the more difficult.

Still other characteristics of lagoon and estuarine fisheries limit the alternatives to the application of regulatory management techniques. Among these characteristics are that fishermen are widely dispersed and that fishing grounds, fishing times and landing sites may vary widely. Thus, regulatory techniques which would involve monitoring of fishermen while they are engaged in fishing, or at landing points, would of necessity be expensive in terms of the numbers of enforcement personnel required. Therefore, governments would find difficulty in funding such expensive enforcement activities.

Another factor which complicates regulation of fishing or of fishing gears on the fishing grounds is the often complex and varied nature of the fishing gears utilized, as exemplified by the Chilka Lake fisheries (Section 2.2). In this situation measurement of gear selectivities and efforts cannot be easily accomplished and therefore gear specification and effort cannot be practically regulated unless a specific gear type is entirely eliminated from the fishery through legislation.

Within the context of coastal lagoon and estuarine fisheries as they presently exist in most developing countries, management of fisheries is probably most easily applied (and has the best possibility of becoming more effective in the future) when regulation is aimed first at the most destructive of fishing practices. In this situation the majority of fishermen themselves can then readily appreciate the benefits of regulation. An example of such a situation in which regulatory management can be readily implemented is the blockage of inbound and outbound reproductive migrations and the fishing of juveniles by fixed gears set in lagoon/sea access channels.

Another possibility which seems workable at first sight is the maintenance of minimum size or length regulations through monitoring of the marketed catch and by holding marketers responsible for maintaining the size standards through penalties. This method has the advantage of requiring a relatively small and thus inexpensive enforcement staff for maintenance of a straightforward management objective. However, even such a low-complexity management method might present difficulties in some fisheries, namely that in many artisanal fisheries a significant proportion of the catch may go for subsistence or local sale, and may not enter formalized marketing channels. Another draw-back is that in some fisheries processing may be undertaken by the fishermen themselves and size-regulated fishes or crustaceans may be unidentifiable for measurement after processing. Examples of extreme cases are the practices of using undersized fishes and shrimps for sauces or pastes, but sun-drying, prevalent as a preservation method almost everywhere in the tropics and sub-tropics, would have a similar effect. Thus, enforcement of size regulations would have to be undertaken at usually widely dispersed fish landing sites. This regulatory method is therefore best applied to high value fishes, crustaceans and molluscs where quality maintenance demands centralized processing and where monitoring can be relatively easily undertaken.

2.3.3 Revitalization of traditional management practices

An alternative to the regulation of lagoon and estuarine fisheries through central government intervention is the possibility that traditional fishery management practices could be revitalized or

reinforced. Such traditional fishery management practices have evolved over centuries to conserve fishery resources while at the same time providing an equitable distribution of resource wealth among fishing communities.

Fishery management by traditional means is probably fast disappearing; however, there are indications that these traditions still remain in force in some areas. For example, "self-regulation" by traditionally engendered controls still works in parts of the Ghanian lagoon system. There, lagoon ownership is held by the adjacent village or town and the lagoon itself has a religious status. Regulation of fishing is controlled by a Chief Fetish Priest and is exercised in the form of closed seasons (Mensah, 1979). Fetishes also play a role in the regulation and allocation of fishing in the lagoon systems of Benin (Welcomme, pers.comm.). In Nigeria, where lagoon oyster fisheries have been in decline for some time, to safeguard against further depletion, the villagers themselves have enforced management regulations including licensing, closed seasons and quotas (Ajana, 1980).

Although the traditional fishing industry in the Lagune Ebrié in Ivory Coast has been disrupted by the influx of expatriate fishermen, gears, and capital, in another lagoon in the same country fishermen themselves decided not to permit the entry of new gears (Garcia, pers.comm.).

In the estuarine fisheries of the Bahia State of Brazil, Cordell (1974; 1978a and 1978b) has shown that a complex of factors has been evolved over four centuries to match traditional canoe fishery exploitation to the resources available to the fishery. Among the means which have been evolved to ensure rational exploitation of the resources is a system of keeping the detailed knowledge for prediction of tides and currents, necessary for fishing success, within tight-knit family groups which are limited in number. The establishment of proprietary fishing rights to certain fishing areas which are passed from one generation to the next was probably the most important development to rationalize exploitation. Other factors included a cooperative attitude within the fishing community, and community social pressure.

In order to revitalize traditional fishery management where its practice is fast disappearing, or to reinforce it where it is still in force, would, however, require indepth studies of the sociological/anthropological/economic aspects of traditional fisheries such as those conducted by Cordell mentioned above. But it seems that this approach, if successful, could be quite viable, and in the long run, economic when compared to the costs and difficulties of management programmes instituted and wholly enforced by central governments. After the mechanisms involved in traditional fishery management had been studied and understood, steps could then be taken by central government authorities to formally legalize traditional regulatory institutions and to reinforce traditional regulatory authority. For example, the first attempt at a unified fishing law for Japan in 1901 recognized and legalized a major part of the existing traditional fishing institutions and practices (Asada, 1973).

In summary, many "classical" regulatory fishery management techniques have been proposed to solve the various kinds of fishing problems identified in the lagoons and estuaries of developing countries -- closed seasons, closed areas, limited entry of gears and fishermen, and gear regulations; however, the literature is much less replete with examples of the successful employment of these regulations which are accompanied by measurements of the benefits which have accrued to fishermen and the costs which are incurred for the management strategies adopted. Bardawil lagoon was the only exception found. There it was demonstrated that classical regulatory approaches to fishery management can be successful if implemented in the near ideal circumstances of high-value resources, strong but benevolent administration, adequate and appropriate research on which to base management strategies, and sufficient means for strict enforcement of management regulations. However, in what is the more usual circumstance in the coastal lagoon and estuarine fisheries of developing countries, the most potent forms of regulatory management may be inappropriate or inapplicable for a complex of sociological, economic, and political reasons, or the information may not be sufficient to formulate appropriate management policies. Nevertheless, in this situation a start can be made by attempting to address the most serious management problems through regulation of the most destructive fishing practices. As an alternative to the imposition and enforcement of management regulations by central government authority, or as a supplement to such management, it may be possible to revitalize or reinforce those features of traditional fishery control which historically conserved fishery resources while providing fishing communities with an equitable share of resource wealth.

## 3. NON-REGULATORY MANAGEMENT OF LAGOON AND ESTUARINE FISHERIES

In this section the focus is on some management techniques which can supplement or complement the more classical regulatory management strategies which have been illustrated in the preceding section. Non-regulatory management in the sense used here is the application of various techniques to increase aquatic productivity and hence fishery potential. Firstly, some different applications of hydraulic management of lagoons for fisheries are discussed as a means for significantly improving capture fishery and aquaculture yields. Secondly, some additional non-regulatory management tools such as predator control, stocking, creation of artificial nursery areas, and brush-pile fisheries are examined.

### 3.1 Hydraulic Management of Lagoon Fisheries

Hydraulic engineering for fisheries is viewed herein as one of the most promising means available for management and development of capture fisheries and aquaculture in lagoons and estuaries. Basically, hydraulic engineering is the means whereby environmental conditions are manipulated through varying freshwater and seawater inputs so as to increase aquatic productivity and hence fishery yield.

The need for hydraulic engineering for fisheries is often brought about by the natural dynamic evolution of coastal lagoon systems -- internal sedimentation, and silting up of connections with the sea by littoral transport -- but increasingly by man-made alterations of the environment which accelerate natural ageing or decrease aquatic productivity in other ways.

Some examples of the kinds of engineering works used in coastal lagoons worldwide to benefit fisheries are portrayed in Table 1, along with some examples of specific lagoons in which hydraulic engineering has been applied, or the need for it identified.

Channelization from the sea to a lagoon or lagoon system is an obvious solution for increasing fishery production in lagoons which would otherwise go completely dry, such as Bardawil in Egypt (Ben-Tuvia, 1979) or periodically go so extremely hypersaline that almost no fish life can be supported such as Laguna Madre de Tamaulipas in Mexico (Hildebrand, 1969). If lagoon-sea connections are not maintained, temperature and hypersalinity can also cause massive fish mortalities such as in Laguna Unare in Venezuela (Mago Leccia, 1965).

In less extreme cases the maintenance of the lagoon connection with the sea can be used to stabilize environmental conditions so that what beforehand was a seasonal fishery can be extended throughout the entire year.

Edwards (1978a) indicates that in Mexico it is generally believed that lagoons of the semi-isolated kind should remain largely so because the fauna is adapted to the brackishwater environment, and therefore artificial connections made with the sea should be furnished with control gates for salinity regulation. Along these same lines in the Laguna Sinoe of 17 000 $hm^2$) in Romania, maintenance of a relatively low salinity within rather narrow limits is advantageous for the fishery to ensure that conditions favouring the economically most important species, mostly freshwater forms, are maintained (Valerian, 1977).

In addition to salinity control, maintenance of the lagoon-sea connection permits the ingress and egress of estuarine dependent, marine transient, and anadromous and catadromous finfishes and crustaceans on which many lagoon and estuarine fisheries are largely dependent, such as those for shrimps, prawns, and mullets worldwide, for Hilsa (shad) in India and for Ethmalosa in West Africa.

Site selection for the channels may be made in such a way that the time and distance for inward migration is considerably reduced as in the Mexican La Joya-Buenavista system from 30 km to 5 km (Huerta Maldonado, 1980) and in the Huizache-Caimanero system (Edwards, 1978a) thereby allowing for an earlier arrival, increased survival, and longer growing period for shrimp. The channel may be designed in such a way as to concentrate fishes or crustaceans for capture during outward migrations (Edwards, 1978a).

Table 1. Some objectives of hydraulic management of lagoons for fisheries and examples of applications or needs identified

| Country/ lagoon | Surface area ($hm^2$) | Channels from the lagoon to the sea | | | Diversion canal(s) from rivers to lagoon | | Internal canals | | Diversion of fresh waters away from lagoon | References |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Fish/crustacean ingress/egress | Combat hyper-salinity | Reduce pollutant load | Combat hyper-salinity | Maintain or increase lagoon surface area, or for enrichment | Promote circulation | Fish/crustacean access to isolated lagoons or areas | Reduce or eliminate domestic, agricultural, or industrial pollution | |
| **VENEZUELA** | | | | | | | | | | |
| Unare | 4 400 to 6 400 | | X | | X | | | | | Okuda, 1965 |
| Piritu | 700 to 3 700 | | | | X | X | | | | Posewitz, 1968 |
| **EGYPT** | | | | | | | | | | |
| Bardawil | 65 000 | X | X | | | | | | | Ben-Tuvia, 1979; Pisanty, 1980 |
| Manzalah | 117 000 | X | X | | | | | | | Wahby and Bishara, 1977 |
| **TUNISIA** | | | | | | | | | | |
| El-Biban | 30 000 | X | X | | | | | | | Medhioub and Perthuisot, 1977 |
| Lac Tunis | 4 200 | | | X | | | | | | Stirn, 1966 |
| **MOROCCO** | | | | | | | | | | |
| Sebkha Bou Areg (Lagune de Nador) | 11 500 | X | X | X | | | | | | Aloncle, 1961; Brethes and Tesson, 1978 |
| **GHANA** | | | | | | | | | | |
| Keta | 2 150 | X | | | | | | | | Mensah, 1979 |
| **MOZAMBIQUE** | | | | | | | | | | |
| Pangalanes Est | 18 000 | X | | | | | | | | Collart and Randriamanajina, 1978 |
| **INDIA** | | | | | | | | | | |
| Pulicat | 39 200 | X | X | X | | | | | | Menon and Raman, 1977 |
| Chilka | 90 600 to 116 500 | | | | | | | | | Jhingran and Natarajan, 1969 |
| **SRI LANKA** | | | | | | | | | | |
| (Lagoons) | – | X | | | | X | | | | FAO/UN, 1962 |
| **MEXICO** | | | | | | | | | | |
| Huizache-Caimanero | 7 100 to 14 800 | X | | | | X | X | X | | Edwards, 1978b |
| Laguna Madre de Tamaulipas | 215 600 | X | X | | X | | | | | Sanchez, 1980; Martinez Mata, 1980 |
| Menchaca, Camarón, Playa Cerrito | 16 700 | | | | | X | | | | Juarez Reyes, 1980 |
| (Lagoons) | – | X | X | X | X | X | X | X | X | Cervantes Castro, 1980 |

Other specific and inter-related purposes of hydraulic engineering in maintaining the lagoon-sea connection for fisheries are for promotion of circulation to carry away domestic, industrial, or agricultural pollutants as is the case with the former in the Lac Tunis (Stirn, 1966) and to increase aquatic productivity as in the nutrient depauperate Panganales Est lagoon system in Madagascar (Collart and Randriamanalina, 1978). Further, such lagoon-sea connections may be also used for improved navigation so that fishery products can be transported from the lagoon by sea to markets or processing plants, and so that supplies can reach isolated fishing communities.

Engineering works within the lagoon also serve a variety of purposes such as providing increased surface area for fishing, and passage of fishes and crustaceans from one water body to another by connecting adjacent lagoons. Interconnecting channels also allow larval fishes and shrimps improved access to nursery areas (see Fig. 4). Reduction of sedimentation and promotion of circulation are yet other purposes of internal canals (Cervantes Castro, 1980).

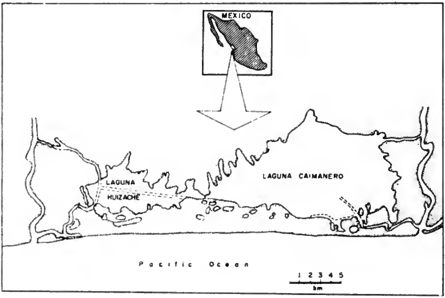



Fig. 4. Hydraulic engineering within lagoon systems as exemplified by the Huizache-Caimanero lagoon complex in Mexico (from Edwards, 1978a)

Diversion of fresh waters to lagoons from nearby rivers or streams is usually accomplished to reduce salinity. For example, Okuda (1965) has proposed an ambitious scheme for diverting Rio Unare waters (Venezuela) to the Laguna Unare to reduce hypersaline conditions during the dry season, and Posewitz (1968) has advocated the use of an upstream reservoir and pumping or gravity feed of fresh water to supply the Unare and adjacent Piritu lagoon with fresh water while eliminating sedimentation from the Rio Unare. Diversion of river waters through seven channels to the Laguna Madre de Tamaulipas (Mexico) has produced favourable conditions for oyster culture there (Sanchez, 1980). In the Huizache-Caimanero system, diversion of river waters has been used to maintain a larger lagoon surface area for a longer duration to benefit survival and growth of shrimp. Circumstantial evidence points to a significant increase in shrimp yield from the system as a result (Edwards, 1978a). Juarez Reyes (1980) mentions the construction of crude temporary dams in three lagoons, presumably across lagoon outlets, to maintain higher water levels for longer periods for the same purpose. As one means to produce better conditions for the reproduction and survival of the eggs and larvae of the anadromous Hilsa in the Hooghly-Matlah estuarine system in India, Gopalakrishnan (1977) suggested the timed release of water from upstream reservoirs.

Finally, the logical extension of hydraulic engineering for fisheries is the creation of new lagoons. For example, hydraulic engineering has been used to create the artificial Lagune de Khenis of 350 $hm^2$ in a part of the Baie de Monastir in Tunisia. This lagoon supports a capture fishery and is being increasingly developed for aquaculture.

Although the benefits of hydraulic engineering in lagoons for fisheries are obvious, economic data of a cost-benefit nature are difficult to locate. Huerta Maldonado (1980) provides finfish and shrimp yield data which show a notable increase after the construction of a canal from the sea to the La Joya-Buenavista lagoon system and remarks on the comparatively rapid growth and large sizes of the shrimp harvested from the system. After extensive hydraulic management the Huizache-Caimanero lagoon system has a very high average shrimp yield, 126 kg $hm^{-2}$ $yr^{-1}$ (from Edwards, 1978a). Laguna Madre de Tamaulipas produced about 42 kg $hm^{-2}yr^{-1}$ of finfishes, crustaceans, and molluscs in 1977 (Martinez Mata, 1980) with only limited hydraulic management whereas historically (Hildebrand, 1969) there were periods when the fishery was severely reduced or non-existent without hydraulic management.

Posewitz (1968) estimated that the engineering works necessary to provide the Piritu and Unare lagoons with fresh water during the dry season would require U.S.$200 000 with $10 000 $yr^{-1}$ for maintenance but that the value of the additional fishery yield made possible by the engineering works would be about U.S.$90 000 $yr^{-1}$.

Of the information available, Pisanty (1980) provides the most complete picture of the benefits of hydraulic management for the Bardawil lagoon in Egypt. Bardawil, like the Laguna Madre de Tamaulipas, supported a boom or bust fishery from early in this century because of wide variations in salinity. There, without an opening to the sea, the lagoon, of 65 000 $hm^2$, can dry-up completely (Ben-Tuvia, 1979).

Early in this century with sporadic dredging of channels, or with natural but temporary openings caused by storms, the lagoon produced about 5 kg $hm^{-2}$. In the late 1960's and through most of the 1970's the lagoon was brought under well-organized management which included opening two permanent channels to the sea which were dredged every other year, applied research on fishery resources, regulation of the fishery, and an agressive programme of export marketing. A 15 percent tax levied on the gross value of the catch (3.8 to 5.5 million dollars from 1975 to 1978) supported the bi-annual maintenance of the channels (12 percent) and the remainder supported research and administration of the fishery (3 percent). Yield from the lagoon with hydraulic and other management activities was increased to an average of 31 kg $hm^{-2}yr^{-1}$ and the value of the fishery was increased ten-fold for the latest years of data available, whereas in the past without hydraulic engineering no sustainable fishery existed.

In order to be successful, hydraulic management of lagoons should be based on detailed engineering studies as well as on thorough chemical, physical, and biological surveys. The basic kinds of hydraulic studies which are required are: longshore drift, tides, sedimentation, freshwater input, rainfall, evaporation, occurrence of storms and hurricanes, as well as other physical and chemical

investigations including those of surface area, bathymetry, and temporal and spatial distribution of salinity (Cervantes Castro, 1980).

Biological and limnological studies in connection with hydraulic engineering in Mexico are usually aimed at providing information for optimum operation of hydraulic structures. These studies relate information on shrimp and fish distribution, movements, and growth to physical and chemical measurements of the lagoon environment, examples of which can be found for various lagoon systems in Gezan Soto (1976), Barrera Huerta (1976), Huerta Maldonado (1980), Martinez Mata (1980), and Sanchez (1980).

Elsewhere, studies such as those by Tesson (1977) and Brethes and Tesson (1978) on the Sebkha Bou Areg in Morocco and by Okuda et al. (1965), Benitez Alvarez, and Gomez (1965), Okuda, Garcia, and Benitez Alvarez (1965), Okuda (1965) and Fukuoka and Gamboa (1973) on the Laguna de Unare in Venezuela provide examples of how short-term intensive investigations can point-up hydraulic and other problems in lagoons which suggest the appropriate hydraulic engineering solutions. The investigation reported by Amanieu et al. (1980) on a small semi-artificial lagoon on the Mediterranean coast of France porovides an excellent example of how, by detailed biological monitoring of the effects of experimentally controlled seawater input, indications for the optimum strategies for future hydraulic management can be derived.

It seems that much useful information from aquacultural engineering and from the results of coastal aquaculture in small systems could be brought to bear on problems of hydraulic engineering in lagoons, but no study which has attempted to accomplish this on a systematic basis has been found in connection with this review.

### 3.2 Predator Control

Edwards (1977) based on his field investigations on the Huizache-Caimanero lagoon complex, noted that total mortality of shrimp between post-larval and late juvenile stages is relatively high. Recruitment provides up to about 10 post-larvae $m^{-2}$ of lagoon bottom, but subsequent mortality decreases the number of juveniles to about 0.3 $m^{-2}$ for most of the lagoon area. In comparison, results of cage experiments indicated that shrimp densities of up to 2.5 $m^{-2}$ could be supported without loss of growth. Based on these results and the results of enclosure experiments elsewhere which showed that shrimp harvest rates could be increased by a factor of about 3 in the absence of predators, Edwards (1977) concluded that the establishment of a fishery for the main shrimp predators in lagoons, Galeichthys, Cynoscion and to some extent Callinectes, could reduce shrimp mortality and increase yield. Wing nets set in channels would be appropriate for Galeichthys, and Callinectes could be fished by pot traps. Thus, not only would shrimp production be increased, but a more rational use of the lagoon fishery resources would result by making greater use of finfish and crabs.

### 3.3 Stocking

Garduño Argueta (1976), in remarking that offshore and lagoon shrimp resources of the Pacific coast of Mexico had surpassed their maximum level of exploitation, points out that one way to realize a greater shrimp yield is through the artificial cultivation of shrimp in hatcheries based on collection of gravid females and culture of larvae for release at post-larval and juvenile stages for stocking in lagoon waters. The same author reports on some pilot work in shrimp rearing but the investigation did not proceed as far as evaluating the contribution of stocked shrimp to fisheries. Edwards (1977) believes that such stocking can be successful only if the hatchery-reared shrimp are first released into enclosures from which predators have been excluded.

The Japanese have engaged in stocking of open but protected inshore waters with Penaeus japonicus since 1968 (Shigueno, 1975). Although the results of these stockings have been difficult to assess, it appears that best results are produced when stocking is accomplished in the inner parts of bays. "Artificial tidelands" have been created as a means to enhance the success of stocking through a better acclimatization to natural waters (Honma, 1980) (Fig. 5).

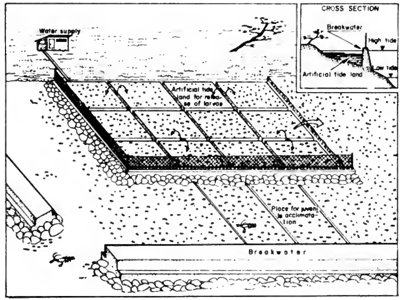



Fig. 5. A schematic diagram of an "artificial tideland" for shrimp stocking in Japan (from Honma, 1980)

Intensive stocking of Cyprinus carpio, Sarotherodon niloticus and mullets in the Pangalanes Est lagoon system of Madagascar has been advocated by Collart and Randriamanalina (1978). Some exotic species had been introduced previously, but without notable success except for other Tilapia/Sarotherodon introductions. Mullets occur naturally. These authors note that to increase chances of success, stocking would have to be accomplished repeatedly and in large numbers, and that juveniles would have to be kept in predator-free enclosures until they reached a stockable size.

Texas (U.S.A.) is making an effort towards the stocking of bays (coastal lagoons) with red drum, Sciaenops ocellata. This fish is under heavy fishing pressure from both recreational and commercial fishermen and is important to the economy which justifies the stocking effort as an extension of the overall bay fishery management programme. This species has been spawned artificially, and the effect of experimental stocking was to be evaluated. It is noted, however, that there is no advantage to be realized if the stocking and natural production exceed carrying capacity, or if the resource continues to be over-harvested (Hefferson and Kemp, 1980).

Victoria (Australia), too, is contemplating artificial rearing and stocking of finfishes in inshore waters if practical benefits can be thus realized for the enhancement of fisheries (Winstanley, 1981).

### 3.4 Artificial Nursery Areas

As a management measure for the Pangalanes Est, Collart and Randriamanalina (1978) recommended the creation of artificial spawning areas using various types of local plant materials. These would be located in protected areas of the lagoon, and predators would be removed on a periodic basis using electric fishing.

On a much more sophisticated scale, the Japanese (Honma, 1980) have actively developed a variety of artificial structures to serve as nursery areas for prawns and fishes including breakwaters and man-made weed beds (Fig. 6). Although such structures are economic in Japan, and although their use could contribute to the enhancement of lagoon and estuarine fisheries elsewhere in the world, it will probably be some time before such elaborate engineering for fisheries becomes cost effective in developing countries.

#### Other non-regulatory management methods

In a review article on fish cropping and production in estuarine waters, Saila (1975) observes that the potential for enhancing fish production in estuarine waters has yet to be fully realized. Among the management measures that he recommends for consideration and additional research and experimentation are controlled artificial enrichment, transplantation, predator control, and controlled breeding.

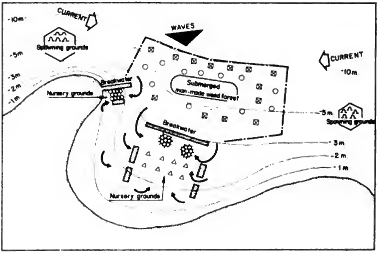



Fig. 6. An artificial shrimp nursery complex in Japan (from Honma, 1980)

### 3.5 Brush-park Fisheries

Brush-park fisheries are a traditional form of low-technology aquaculture which is practised in inland and brackish waters in many areas of the world. The brush parks are constructed in a variety of forms and sizes, but basically a brush park consists of an inner core, or concentric circles, of densely packed tree branches or other material surrounded by an outer, more substantial wooden framework which is fished periodically, usually by encirclement (Figs. 7 and 8).

In coastal lagoons the most sophisticated forms of brush-park fisheries occur in Benin. Elsewhere in Africa, brush-park fisheries are found in Nigerian coastal lagoons (FAO, 1969) and in coastal lagoons in Ivory Coast (Kapetsky, pers.obs.), Ghana (Mensah, 1979), Togo (Welcomme, 1971, 1972; Everett, 1976) and Madagascar (Kiener, 1960, 1963; Moulherat and Vincke, 1968). Elsewhere in the world, brush-park fisheries are found in Negumbo lagoon in Sri Lanka (FAO/UN, 1962) and have been recently introduced in some Mexican lagoons (Lizarraga, pers.comm.). In rivers and lakes traditional brush-park fisheries are found in Cameroon (Stauch, 1966), in Sierra Leone (Chaytor, pers.comm.), in Nigeria (Awachie and Ezenwaji, in press; Reed, 1967), Bangladesh (Kapetsky, pers.obs.), Kampuchea (Fily, 1966), China (C.S.F.F.C.E.C., 1972), and Ecuador (Meschkat, 1972).

Brush-park fisheries appear to offer a number of advantages for the management of coastal lagoon fisheries, and therefore their characteristics are examined in detail in the following sections.

#### 3.5.1 Brush-park fisheries in Benin

Buffe (1958), FAO/UNDP (1971), and Welcomme (1971, 1972) have provided detailed information on brush-park fisheries in Benin where they are known collectively as "acadjas", and Bourgoignie (1972) has studied their historical development over the last two centuries.

There are several basic types of brush-park fisheries in Benin which vary from each other in configuration, construction and fishing characteristics (Figs. 7 and 9). The acadjas are constructed of tree branches with harder woods forming the peripheral structure and with soft wood branches with many ramifications forming the interior of the acadja.

Acadjas are preferentially placed in shallow, quiet waters of no more than 1.5 m depth.

Fishing is accomplished by surrounding the smaller types of acadjas with a net after which all of the branches are removed and the net is then pursed. For the larger brush parks the surrounding net is fished in a step-wise process by gradually moving the net inwards as branches are removed until the fish are concentrated in small areas and can thus be removed with traps, baskets, and hand-nets. After fishing, the used branches are replaced and new ones added, as necessary (Welcomme, 1972).

Yields from the various kinds of acadjas are variable, but high. Buffe (1958) provides data showing yields of 13.6 and 19.2 t $hm^{-2}$ for ava-type acadjas for periods varying by only a few days from a full year, and mentions annual yields from other avas at about 10 t $hm^{-2}$. Welcomme (1972) provides yield data by type of acadja.

Tilapia melanotheron and Chrysichthys nigrodigitatus dominate the acadja fisheries (67 to 95 percent by weight), but open water fisheries are based mainly on other species such as Ethmalosa fimbriata.

Welcomme (1972) has analysed the relationship between yield and the length of time of implantation, the effect on yield of frequency of fishing, and also the relationship between density of branches and acadja yield. The former was analysed for two periods, 1957-59, and 1969-70. The relationships thus derived (Fig. 10) have been interpreted to show that three dynamic factors successively influence yield: immigration of fish into the acadja (colonization), growth and reproduction within the acadja, and possibly emigration from the acadja, while basic yield potential is significantly influenced by density of branches used.

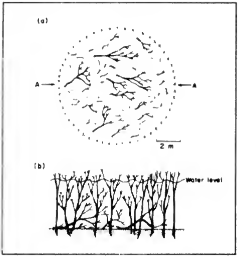



Fig. 7. Diagramatic representation of a godokpono-type brush-park fishery in Benin. (a) Plan; (b) Section. x = hardwood branches; ∴ softwood (from Welcomme, 1972)

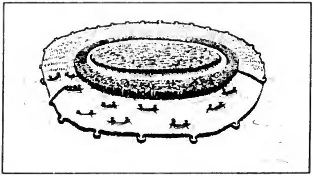
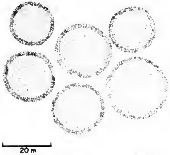
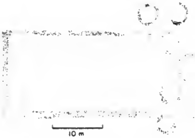


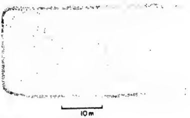
Fig. 8. A brush, reed, and rice grass-park fishery in China (from C.S.F.F.C.E.C., 1972)




Plan of an odokpo consisting of a group of 6 circular acadjavis.




Plan of an hanou




Plan of an hanoumecodja

Modification of an hanoumecodja to facilitate fishing

Fig. 9. Various kinds and configurations of brush-park fisheries in Benin (from Welcomme, 1972)

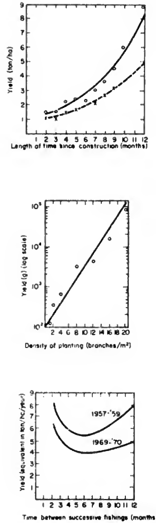



Fig. 10. Yields from brush-park fisheries in Benin as a function of time since construction (O, 1957-59; x, 1969-70), density of branches, and time between fishings (from Welcomme, 1972)

Composition of the fish population of acadja avas as compared with that of the open waters of Lake Nokoue (from Welcomme, 1972)

| Species | Percentage by weight | |
|---|---|---|
| | Acadja | Open water |
| *Tilapia melanotheron* | 72.6 | 0.7 |
| *Chrysichthys nigrodigitatus* | 23.8 | 1.4 |
| Other species | 3.6 | 97.9 |

Before physical and economic disruption of acadja fisheries by teredo attack on their branches and by deposit of calcareous deposits limiting epiphytic production caused by the permanent opening of a lagoon/sea channel, the Lake Nokoué-Porto Novo lagoon capture fisheries were perhaps the world's most productive with yield estimates (acadja plus capture fisheries) of more than 1 t $hm^{-2}$ prior to 1958 (Buffe, 1958) and about 1.8 t $hm^{-2}$ from 1957 to 1958 (Lemasson, 1961)1/, and at least the most productive that have been found in connection with this review. Even with the subsequent decrease of acadjas, lagoon fishery yields there had decreased to only about 357 kg $hm^{-2}$ in 1969 (76 kg $hm^{-2}$ of this total contributed by acadjas) which is still at a level much higher than the yields obtained in other West African lagoons where acadja fisheries do not exist or are not prevalent.

Since the construction of a cross-channel barrage which reduced lagoon salinities somewhat and hence teredo attack on acadja branches, and because of other favourable economic conditions, acadja fisheries are once again proliferating in the Lac Nokoué/Porto Novo lagoon system (Fig. 11). Total acadja yield in 1980-81 in the 15 700 $hm^2$ system is estimated at about 2 000 t from about 390 $hm^2$ of acadja installations (Welcomme, unpublished), equivalent to a yield of about 127 kg $hm^{-2}$ if taken over total lagoon surface area.

3.5.2 Brush-park fisheries in coastal lagoons elsewhere in the world

Elsewhere in West Africa, lagoon brush-park fisheries are known from the Keta lagoon system in Ghana, from the Lagos-Lekki lagoon system in Nigeria, from Lac Togo lagoon in Togo, and from Ebrié lagoon in Ivory Coast; in East Africa, they are used in Madagascar. However, published material providing details on these fisheries is scarce.

In Lac Togo it appears that in the early 1970's there were about 35 $hm^2$ of acadjas which yielded about 14 t $hm^{-2}yr^{-1}$ (Togo, 1971), equivalent to about 82 kg $hm^{-2}yr^{-1}$ taken over the total lake surface area of about 6 000 $hm^2$.

Information of brush-park fisheries in Nigeria is dated (FAO, 1969) but the brush parks were said to be common in Lagos and Lekki lagoons, a lagoon system contiguous with the Benin lagoons. These were constructed of tree branches and palm fronds. Frequency of fishing was evidently at from 2 to 3 month intervals, and the most common fishes in the catch were tilapia and mullet.

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1/ In 1959 total yield was about 980 kg $hm^{-2}$ of which open water capture fisheries accounted for 715 kg $hm^{-2}$ and acadja fisheries 237 kg $hm^{-2}$ (FAO/UNDP, 1971)

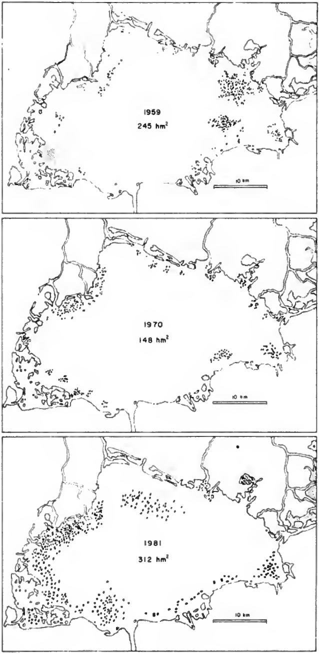


Fig. 11. Total surface area and distribution of brush-park fisheries in Lac Nokoué, Benin, in 1959, 1970, and 1981 (from FAO, 1971, and Welcomme, unpublished)

In Eastern Ghana in the Keta lagoon area, Mensah (1979) mentions that brush-park fisheries of the circular "godokpono" type (Fig. 7), there called "achidjas" vary in size from 150 to 300 $m^2$ and are fished every three to four months. On a visit to the lagoon area in February 1981 (Kapetsky, pers.obs.) brush-park fisheries were observed at several places around the lagoon periphery. These were of two types, the first as described by Mensah (1979) (above), but much smaller in area, from about 7 to 50 $m^2$, and common in occurrence. The other type was a smaller version of the "adokpo" (Fig. 9) with a number of small circular brush piles of 1 to 2 m diameter grouped to form a rectangular shape. Based on very limited information from an interview it was gathered that these fisheries have been in use at the Keta area for more than a lifetime, each fishery is individually or family owned, fishing intervals are from one to two months, and the principal species caught is tilapia. Yields from a 3-m diameter (7 $m^2$) "godokpondo" averaged about 15 kg per fishing (about 20 t $hm^{-2}$, but varied from considerably less up to about 30 kg per fishing. Teredo attack on the wood used in the "achidja" fisheries had been a problem of annually varying proportions stemming from a time about 13 years previous when the lagoon was directly, but temporarily, connected with the sea.

In the Lagune Ebrié, Ivory Coast, brush-park fisheries also of the godokpondo type had been recently introduced in one area near Abidjan about four years ago by fishermen originally from Benin. In March 1981 (Kapetsky, pers.obs.), these numbered 25, of about 2.5 to 3.5 m in diameter, distributed along about 4 km of a narrow arm of the lagoon. From interviews with five owners, a general idea of the yield and economics of these fisheries was gathered. As in Keta lagoon in Ghana, yields averaged about 15 kg per fishing of a brush pile slightly larger than 3 m in diameter, with one fishing every two months. Yields varied from about 7 kg per fishing to about 40 kg (8 to 42 t $hm^{-2}$ per fishing). Tilapia and Lutjanus were said to be the most common fish in the catch. Because of the proximity of these brush-pile fisheries to the lagoon/sea connection, teredo attack on the branches is intense, necessitating complete replacement of branches every 4 to 6 months. The information volunteered by the owners on wood costs and wood replacement rates enabled the calculation of an approximate break-even cost for the average brush-park fishery. The average price of fish paid to fishermen in the area, obtained independently, and the information provided by the fishermen on yield was consistent with the break-even cost, suggesting that the information obtained was fairly reliable. That the brush-park fisheries are economic, even with high wood replacement rates of 200 to 300 percent $yr^{-1}$ (compared with a current 36 percent $yr^{-1}$ rate in Benin) is also evidenced by their gradual increase in numbers over the last four years.

About one week subsequent to the author's visit to the brush-park fisheries of the Lagune Ebrié, personnel of the Centre de Recherches Océanographiques, Abidjan, observed the fishing of one brush park of the same 25-unit cluster, on 9 March 1981.

The brush park was about 4 m in diameter, and had been last fished 70 days previous. The yield consisted of the following species and quantities of fishes:

| | |
|---|---|
| Lutjanus goreensis | 15.75 kg |
| Tilapia heudeloti | 3.60 |
| Epinephelus aenus | 1.20 |
| Psettus sebae | 1.20 |
| Pommadasys jubelini | 0.60 |
| Chrysichthys walkeri | 0.50 |
| Tilapia guineensis | 0.30 |
| Gerres nigri | not weighed |
| | 21.15 kg |

The fish yield from this fishing was equivalent to about 17 t $hm^{-2}$.

In addition to the fishes tabulated above, Bert (unpublished) notes that a very abundant fauna associated with the branches was also observed including shrimps, crabs, small fishes, and molluscs.

Brush-park fisheries have been recently observed in two other areas of Lagune Ebrié (Durand, pers.comm.) but no details on them are yet available.

Other than from West Africa, the only quantitative information on coastal lagoon brush-park fisheries comes from Negumbo lagoon in Sri Lanka (FAO/UN, 1962), from a single experimental installation in Madagascar (Collart and Randriamanalina, 1978), and from traditional brush-park fisheries in the same country (Moulherat and Vincke, 1968).

In Negumbo lagoon there are two kinds of brush parks, "Mas Athu" and "Katta". The "Mas Athu" are circular and vary in diameter from 3 to 4.6 m. Construction is of mangrove poles, and branches are placed vertically or slightly inclined in depths of less than 1.5 m depth. Fishing is at intervals of 10 to 15 days. Based on the rough figures given for "Mas Athu" dimensions and catches, yield is estimated herein to be about 7 t $hm^{-2}$ per fishing. Species in the catch are mainly Mugil, Siganus, Ambassis, Etroplus, Glossogobius, Eleotris, Epinephelus, eels, prawns, and crabs. More than half of the catch was of undersized young specimens. In the Negumbo lagoon 200-300 of these fisheries were present in the early 1960's.

The "Katta" type of brush-park fishery is larger, of about 13 to 30 $m^2$ in area, and is placed in deeper waters than the Mas Athu. The main frame consists of palm trunks set vertically with managrove branches coiled around the lower portions of the trunks. Contrary to the usual fishing practice of surrounding the structures with nets, in the "Katta" brush-park, fishing is done by rod and line. Common species attracted are Lates, Gerres, Ambassis, Scatophagus, and Monodactylus (FAO/UN, 1962). No yields are available from this type of fishery.

In the Pangalanes Est lagoon system in Madagascar, a kind of "mini" brush-park fishery is employed called "Vovomora" consisting of a central core of loosely packed ferns surrounded by vertical stakes (Fig. 12). The small version of the vovomora is from 50 to 60 cm in diameter and placed near the shore in depths of less than 80 cm. In certain areas the vovomora reach 1.5 in diameter and are planted in correspondingly deeper water.

The vovomora are fished at 3 to 4-day intervals, and the catch consists of Macrobrachium, and young of Gobius giuris, other small gobids and atherinids. Yield ranges from a minimum of about 2 t $hm^{-2}$ per fishing to about 8 t $hm^{-2}$ with yields up to 20 t $hm^{-2}$ per fishing during the cold season as calculated herein based on approximate data provided by Moulherat and Vincke (1968). For the Pangalanes lagoon system the 2 217 vovomora provided an estimated 57.8 t of fish and shrimp in 1967. Taken over the total surface area of the lagoon system, the vovomora contributed about 5.2 kg $hm^{-2}$ equivalent to 15 percent of the total fish, shrimp and crab yield of the system in 1967.

Collart and Randriamanalina (1978) report on an experimental brush-park fishery of 250 $m^2$ using branches of local trees implanted in the Pangalanes Est lagoon system in Madagascar. After slightly more than a year, the brush park was fished. The yield was equivalent to 252 kg $hm^{-2}$. The species in the yield (percent by weight) were Tilapia rendalli (26.6 percent), Ptychchromis oligacanthus (21.9 percent), Cyprinus carpio (23.0 percent), Gobius giuris (11.3 percent), Paratilapia polleni (8.9 percent) and Sarotherodon mossambicus) (8.3 percent).

### 3.5.3 Some perspectives on the contribution of brush parks to the management of coastal lagoon fisheries

Brush-park fisheries appear to offer a number of biological and economic advantages for the management of coastal lagoon fisheries. Among these are relatively high yield per unit area, the low-level of technology required, the high intensity of labour employed, a potential for increase in the biological productivity of the lagoon system as a whole through nutrient input from wood, and a positive effect on adjacent capture fishery yields. At the same time the dissemination of brush-park fishery "technology" could also create a number of biological and socio-economic problems which might include actual or perceived competition with capture fisheries for space and resources, interference with navigation, eutrophication due to wood nutrient input, increased silting or sedimentation rates due to physical interference with currents and water flows, and local deforestation.

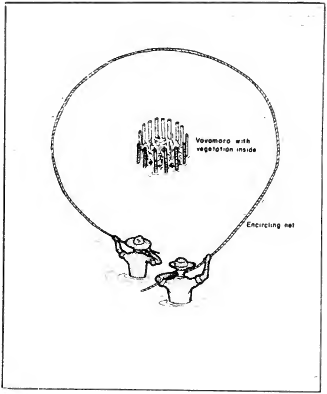


Fig. 12. Fishing of a "Vovomora" in Madagascar (adapted from Kiener, 1960)

Yield

The high yield per unit of area of brush-park fisheries in a wide variety of locations has been demonstrated in the previous sections. However, the frequency of fishing and quantity of wood or other material utilized may influence yield greatly. From the viewpoint of fishery management it is the frequency of fishing which determines whether the brush-park fishery contributes to, or at least does not compete with, adjacent capture fisheries (Welcomme, 1972). From the information available it seems that brush-park fisheries as used in Ghana, Ivory Coast, Nigeria, Sri Lanka and Madagascar, are operated as refuge traps rather than as structures which contribute significantly to aquatic production, and thus, these may compete somewhat with adjacent capture fisheries by attracting fishes away from open-water capture fisheries to the brush parks.

Intensity of Labour

The relatively high intensity of labour required to construct, fish and maintain brush-park fisheries may be an advantage where the economic situation dictates that the quantity of employment generated is a prime consideration in fishery management, especially when compared with the relatively small quantity of labour required for high-intensity mechanized aquaculture. The large quantities of branches required can also contribute to the local economy by fostering a wood growing, harvesting and transporting industry.

Level of Technology

The level of technology required for construction of brush-park fisheries is low relative to some types of "modern" intensive aquaculture, and the fishing skills required are no more complex than for many kinds of capture fishing. This translates to minimal personnel costs to governments for extension services to assist with advice on brush-pile fishery construction and operation when compared with the costs of maintaining such services for other forms of intensive aquaculture.

Contribution to Increased Aquatic Productivity in the Lagoon System as a Whole

There are no hard data to show that nutrient input to a lagoon system through the use of large quantities of wood in brush-park fisheries contributes to increased aquatic production and hence to increased adjacent capture fishery yield. However, the use in Lac Nokoué in Benin of about 30 t of wood $hm^{-2}$ of brush-park installation in 312 $hm^2$ of brush parks with a 36 percent $yr^{-1}$ annual wood replacement rate (Welcomme, unpubl.data from 1981) is equivalent to an annual wood input (wet weight) of about 3 370 t, or 225 kg of wood $hm^{-2}$ if taken over total lake surface area. When nutrient input from wood was compared (crudely) with nutrient input from the two principal freshwater rivers flowing into the system, the former appeared to be inconsequential. Thus, nutrient inputs from wood used for brush-park fisheries are insignificant in quantity in comparison with the introduction of these nutrients to the lagoon by river inflow for the Lac Nokoué situation. Thus, by the same reasoning, eutrophication caused by wood nutrient input does not appear to be an environmental danger.

Competition for Space and for Fishery Resources

Welcomme (1972) provides quantitative data which indicate that the species composition of brush-park fishery catches is different from that of adjacent capture fisheries. Therefore, at least in the Lac Nokoué instance, competition between capture and brush-park fisheries was minimal. Welcomme (1972) also hypothesizes that brush-park fisheries may benefit adjacent capture fisheries quantitatively to some extent if left unfished for long periods, as fish populations build up through reproduction and growth and as some of the individuals disperse to open waters or colonize newly built or recently fished adjacent brush parks.

How the sites and sizes of brush-park fisheries are allocated traditionally among the families and cooperatives of fishermen of open waters of lagoons in Benin and elsewhere is unknown, but an important consideration for management purposes in the dissemination of this technology is that the capture fishermen understand that, if operated properly, brush parks present no threat to their livelihood. Evidently, due to misunderstandings and other sociological or economic pressures, once successful brush-park fisheries in Lac Togo were completely destroyed when it was attempted to rapidly increase their expanse there from about 35 $hm^2$ to 250 $hm^2$ (Togo, 1971; Everett, 1976). Further, brush-park fisheries introduced to Lac Ahémé, Benin, in the late 1960's although initially successful, have now disappeared due to socio-economic and political problems (Welcomme, pers.comm.).

Disadvantages of Brush-park Fisheries

The greatest disadvantage of brush-park fisheries is the large quantity of branches required to establish and maintain the fisheries. This can be disadvantageous in a number of ways -- economically in the cost of purchasing, harvesting, transporting, and installing the wood for initial construction, or for periodic replacement, and with regard to the latter, especially in relation to the intensity of teredo attack and the incidence of other marine infestation.

Environmentally, the large quantities of branches required could contribute to local deforestation and through this, environmental degradation such as erosion, increased sediment loads and increased turbidity which could ultimately adversely affect natural fishery potential. One means to counter this potential difficulty is to establish tree plantations to supply brush-park fisheries, much the same way that tree plantations have been established adjacent to some African cities to supply firewood.

Another potential disadvantage of brush-park fisheries is that they may contribute to the rapid ageing of a lagoon through promoting increased sedimentation rates and hence shallowing of lagoon waters. Although Texier et al. (1980) mention that brush-park fisheries may be a factor in sedimentation in Lac Nokoué, Texier (pers.comm.) does not believe that their influence on this process is great.

Interference of brush parks with navigation in Lac Nokoué, where they are relatively dense, is much more akin to inconvenience than to obstruction at present (Kapetsky, pers.obs.). If necessary, channels could be set aside and bouyed to facilitate navigation through brush-park areas.

Brush-park Fisheries: Summary

Brush-park fisheries offer an attractive, non-regulatory means for management of lagoon fisheries. Among the advantages are high yield, simple technology, high intensity of labour, and low management expense on the part of government. Disadvantages are that brush parks might be perceived by fishermen as competing with already established capture fisheries for fishery resources or for space (or might be operated in such a way that they actually do compete), that large quantities of wood are required for initial construction and for periodic maintenance, and that brush parks might foster some environmental degradation.

The suitability of brush-park fisheries for dissemination as a management technique should be decided based on intensive studies of traditional allocation of fishing rights, fishery biology, fishery and forestry economics, environmental considerations such as possibilities for environmental degradation, and ecological aspects such as the presence of teredos and fouling organisms.

From an economic and environmental viewpoint brush-park fisheries could have a wider potential for dissemination if a cheap, readily available substitute substrate could be found to completely or partially replace the use of tree branches and other natural materials. Such artificial structures are already available as used for artificial reefs in marine waters (Fig. 13), but at this time might not be cost-competitive with natural materials except where the incidence of teredo attack is very high.

4. MANAGEMENT IN THE FACE OF FISHERY INTERACTIONS AND CONFLICTS BETWEEN VARIOUS FISHERIES AND FISHERY INTERESTS

The preceding information on management of lagoon and estuarine capture fisheries has dealt with fisheries and fishery resources almost solely within the context of lagoons or estuaries as isolated biological and economic systems. Emphasis has been on management of the resources themselves. Only passing attention has been given to existing or potential management conflicts between different kinds of fisheries or fishing interests within these waters, and to interactions between lagoon and estuarine fisheries and nearshore and offshore marine fisheries. Thus, in this section examples of several different kinds of conflicts within lagoons are examined -- competition between different economic and ethnic groups utilizing different kinds of fishing gears, conflicts between commercial and sport fishermen as another case, and as a third example, potential conflicts between capture fisheries and aquaculture. Finally, interactions between lagoon and estuarine capture fisheries and offshore and nearshore marine fisheries are considered.

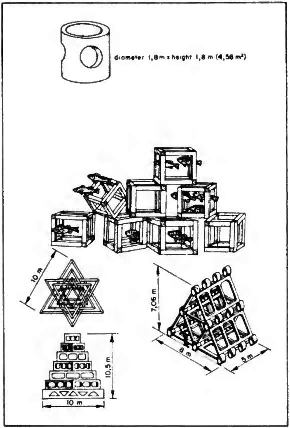


Fig. 13. Artificial fish-attracting structures, from the simple to the complex (from Honma, 1980)

4.1 Conflicts between Artisanal Fishermen of Different Ethnic and Economic Groups

One obvious factor which may cause heavy fishing pressure to be exerted on lagoon and estuarine fishery resources and which can also bring about conflicts among the various groups of fishermen exploiting these resources is, of course, a general increase in coastal populations and a consequent increase in demand for fish for local consumption and for transport to nearby urban centres. The general increase in population is accompanied by an increase in fisherfolk. For example, in Mexico, Acosta Ruíz and Alvarez Borrego (1974) point out that at a time when the coastal fishery resources of Baja California are gradually diminishing under commercial exploitation, the numbers of fishermen in cooperatives are increasing due to demographic increases on the peninsula. Castro Ortiz and Sánchez Rojas (1976) provide graphical data showing an approximate 10 percent annual rate of increase in numbers of fishermen in three large lagoon systems along the Sinaloa (Pacific) coast over the period from about 1940 to 1976, along with trends in yield per fisherman for the most recent years of data. In two of the three lagoon systems trends of yields per fisherman have been decreasing. Barrera Huerta (1976) mentions that one lagoon fishing cooperative in Oaxaça (Pacific Coast) increased from 270 members in 1973 to 355 members between 1974 and 1975. Information provided by Hernandez Carvallo (1976) on shrimp fisheries in Sinaloa suggests that population pressures have led to resource management problems such that cooperatives might have to be reorganized and membership held at actual numbers or otherwise limited to those individuals with land in physical contact with brackish waters. Discussing the socio-economic history of the evolution of shrimp fisheries in the same area, McGoodwin (1979) mentions that with rapid population growth along the South Sinaloa coast (an increase from about 8 000 in 1935 to 35 000 in 1973) there was increased competition for the area's marine resources. The existing fishing cooperatives became entrenched economic entities while the subsistence fishermen, "pescadores libres", were encumbered by various regulations which prohibited their fishing in areas exclusively reserved for cooperatives. Meanwhile, the cooperatives themselves have suffered the effects of population growth from within to the point that they are overloaded and incomes per fisherman are dwindling.

McGoodwin (1979) states that the introduction of the outboard motor and nylon nets aggravated what was already a system under strain. Shrimp and oyster resources were already heavily exploited for export and attention was then turned to finfishes for domestic consumption. But the technological innovations and heavy fishing pressure caused the stocks of the most desirable fishes to be depleted rapidly. Fishermen have now turned to the exploitation of species of secondary economic importance.

The evolution of the Lagune Ebrié fishery (Ivory Coast) documented by Verdeaux (1979) and Gerlotto, Verdeaux and Stequert (1980) provides a good example of the interactions of complex socio-economic factors which must be taken into account in order to develop national or local fishery management strategies for traditional lagoon fisheries.

Ebrié is a lagoon complex of 56 600 $hm^2$ with two natural sea connections and one artificial one. Verdeaux (1979) distinguishes three periods in the evolution of the fishery, the pre-colonial period, the colonial period, and the present period, or, the period of rapid economic expansion. In the pre-colonial period, up to the end of the 19th Century two basic kinds of fishing coexisted, one of which was "community" fishing using large fixed traps constructed of wood and palm fronds and seines of natural fibres. Each of these gears required a number of persons to construct and operate, a family or a village, depending on size. The other kind of fishing utilized gears which were individually operated such as small traps, castnets, and bottom longlines. The catch from individual gears was for daily subsistence and the catch from the blocking traps for preservation and sale. No real fish markets existed, at this time and sale of fish was undertaken by responsible family members.

During the colonial period, from about 1910 to 1958-60, traditional fish commercialization methods by family members were usurped by outsiders. With the marketing structure out of the fishermen's hands, the seines were rapidly abandoned and the large wood traps progressively disappeared from the fishery. The change to individual fishing was also stimulated by the availability of cotton fibres introduced by the Europeans which permitted the construction of enmeshing nets of various kinds which could be fished by a single person. Another factor in the change-over to individual fishing was deforestation which made wood for the wooden traps less available (or more costly), and the opening of an artificial channel, the Canal de Vidri, from the sea to the lagoon to make a port at Abidjan. This

latter event changed salinity conditions in the lagoon and opened the wooden fish traps to destruction by teredos.

The third period, one of rapid economic expansion of the fishery, began in the early 1960's and was characterized by the reappearance of large fishing gears -- beach seines and purse seines -- requiring a number of people to operate them; however, with the innovation that these gears were now owned by non-indigenous people and that the labour for the operation of the gears was salaried.

During the period from 1964 to 1975 the number of fishing gears operated by non-Ivorians increased by a factor of 3.6 while the mesh sizes used in them decreased appreciably. In contrast, practically all of the native Ivorian fishermen use small-scale individual fishing methods which are fixed in location and selective for certain species. The large, active, and non-selective fishing gears are owned and operated by non-indigenous people, mainly Ghanaians but also Sahelian peoples.

The social and economic conflict between the two groups, sometimes violent, has been aggravated by the fact that non-indigenous fishing gears catch about 45 times more than the average catch of the individually operated Ivorian gear, equivalent to 4.5 times as much fish on a catch per fisherman basis. Although the native Ivorian fishermen outnumber the non-indigenous fishermen by a factor of more than three to one, the great bulk of the lagoon yield goes to the latter group. The situation has been further inflamed by the encroachment of the non-indigenous beach and purse seine fishermen on areas of the lagoon reserved by tradition for the individual Ivorian fishermen.

The individual Ivorian fishermen are thus caught in an economic trap in that, their livelihood from fishing is not sufficient to provide them with enough funds to be able to invest in competitive gear. At the same time the non-indigenous fishermen are able to increase their wealth by investing their fishing profits in diversified holdings such as farms, or by reinvesting in fishing gears.

Management of the Ebrié lagoon fishery has to be seen in the context of sociological and economic terms. Both groups view the fishery resources of the lagoon as a means to acquire sufficient funds for investment elsewhere. For the individual fisherman, lagoon fishing is an obligatory step on the way to obtaining sufficient funds for purchasing a small farm. For the owner of a beach or purse seine the resources provide a means of rapid accumulation of money for other profitable investments. Thus, for both groups, the lagoon fishery represents an opportunity for the temporary accumulation of money to be used elsewhere without long-term commitment to conservation of fishery resources. This has led to what Verdeaux (1979) calls a "dynamique de pillage" leading to overexploitation of fishery resources as evidenced by recent catch trends. Berron (1977) provides additional socio-economic detail on the Ivorian situation but with emphasis on marine artisanal fisheries and ethnic conflicts therein.

Another example which points up the need for close socio-economic investigation before fishery management or fishery development programmes can be successfully implemented is that of the near collapse of the traditional canoe fishery of the Valenca delta in the Bahia State of Brazil documented by Cordell (1974; 1978a and 1978b). As mentioned previously (Section 2.3.3) traditional exploitation of the resource was controlled by a social organization which confined the detailed knowledge necessary for prediction of tides and currents and hence fishing success to a relatively small number of fishing captains, the evolution of proprietary fishing rights to certain fishing grounds, and community social pressure.

Disruption of the traditional fishery took place with the purposeful introduction of nylon nets as a means to increase fishery output to supply urban areas. It was also intended that the introduction of nylon nets would benefit traditional fishermen. However, because of the high cost of these new gears, traditional fishermen were unable to afford them and they were purchased by businessmen who employed fishermen on a salary basis for their operation. As a consequence of the entry of the new gears there was a struggle for the control of the existing fishing grounds which resulted in damage to nets and boats. As an additional result, territorial fishing claims were lost and the fishery resource became one of common property. Still other consequences were that while fishery output briefly increased, thereafter catches declined and both the nylon-net fishermen and the traditional fishermen were thus affected. Traditional fishermen then began to use individually operated gears and to extend their fishing to include shellfish while expanding their fishing operations to adjacent mangrove swamp land, much to their economic and social detriment.

The point here is that the introduction of a new, more efficient fishing technology was not inappropriate per se, but that the potential effects of the introduction were not properly accounted for beforehand. This led to social conflict and economic disruption of the traditional fishing community as well as to a likely overexploitation of the resource.

### 4.2 Conflicts between Commercial and Recreational Fisheries

At present, serious conflicts between commercial and sport fisheries in coastal lagoons and estuaries of developing countries are probably nearly non-existent. However, limited information suggests that recreational fishing is becoming increasingly important in some areas. For example, it is believed that about 10 percent of the yield from the 274 000 $hm^2$ of the Brazilian waters of Lagoa Mirim is taken by recreational fishermen ( Machado, 1976). Therefore, the subject is brought up as a possible future management problem based on the course of events in more developed countries where ample leisure time and other economic factors have combined to make sport fishing a significant factor in the exploitation of inland, brackish, and nearshore marine waters. For example, recreational fishing catches for finfishes tend to exceed commercial harvests in five of the seven principal bays along the Texas (U.S.A.) coastline (Hefferman et al., 1979). The management objective in the Texas bay situation is to provide an equitable and sustainable harvest for the two user groups, and a variety of controls are utilized which include quotas on commercial and recreational catch, prohibiting the use of certain gears for certain periods (e.g., week-ends), as well as licensing for both groups (Hefferman and Kemp, 1980). The management programme is based on applied biological research, but major inputs for management controls are determined by direct or indirect monitoring of the activities of both commercial and sport fishermen.

Recreational fisheries are also an important consideration for the management of Australia's estuarine and lagoon fishery resources. The management objectives of the State of Victoria are to ensure accessibility to the resources by the community and to ensure that the resources are conserved for continued community benefit. In this context, the importance of commercial fisheries as the provider of fresh fish to the community is recognized and a goal of management in the face of increasing recreational fishing pressure is to try to maintain the commercial fishery harvest and effort near present levels. Commercial fishing is regulated along two lines. One line serves to conserve resources by regulating commercial fishing where combined sport and commercial harvest is deemed to be excessive or potentially too heavy through closed areas, limitation of entry, and restrictions on gear types. Another line seeks to minimize conflicts or confrontations between commercial and sport fishermen by such means as restricting commercial net fishing on week-ends in estuaries, and bans on all commercial fishing in certain areas for longer periods (Winstanley, 1981).

### 4.3 Aquaculture and Capture Fisheries - Some Potential Conflicts

Many of the authors cited in the previous sections on management have recommended aquaculture as one of the means by which lagoon and estuarine fishery yields could be increased through a more efficient use of the water surface available, through increasing water surface area in suitable fringe areas, and as a panacea for avoiding the necessity and attendant difficulties of managing lagoon and estuarine capture fisheries.

Several kinds of interactions of aquaculture with capture fisheries are foreseen. Those of a biological/chemical/environmental nature, expanded on below, could include changes in water quality and loss of natural productive substrate to aquaculture installations either in the system itself or in the adjacent shoreline areas. Other effects are perhaps more readily evident such as interference of aquaculture installations with capture fisheries, and still others, of a socio-economic nature, are more stuble. In this latter category might be the displacement of labour and livelihood of capture fishermen by aquaculture if the fishermen cannot be accommodated for employment in the aquaculture industry or if they cannot otherwise benefit as owner/operators of the type of culture undertaken. However, apparently little attention has been given by fishery managers, proponents of aquaculture, and socio-economists as to how capture and culture fisheries might beneficially interact, compete, or conflict with each other in coastal lagoons and estuaries, other than from the aspect of environment.

4.3.1 Environmental effects of aquaculture

Odum (1974) treats the impacts of aquaculture in a number of broad categories including aquaculture as a pollution source, special problems of raft culture, physical alterations of the environment, and the introduction of exotic organisms.

Among the adverse consequences of pollution from aquaculture are the changes in composition of natural plant and animal populations brought about by increased or decreased aquatic production, changes in pH, and decreased dissolved oxygen concentration. Where exotic chemicals are used for disease or predator control these may also adversely affect adjacent natural communities.

Considering raft culture as a special case of possible adverse effects because of the high density of shellfishes under culture, Odum (1974) calls attention to lowering of down-current dissolved oxygen concentrations and phytoplankton densities as a consequence of raft culture and thus raft-cultured organisms could be in competition with naturally occurring shellfishes as well as providing adverse conditions for other organisms. Another adverse effect caused by the rafts may be increased sedimentation rates associated with reduction in circulation.

Chesney and Iglesias (1979) have investigated the effects of raft culture of mussels on the distribution and abundance of demersal fishes in the upper part of the Rio de Arosa estuary (Spain) by trawling in raft and non-raft areas of the estuary. Although no surface area is given for the inner part of the estuary by the authors, it seems that the 80 $hm^2$ of rafts which produce about 2 000 t $hm^{-2}$ annually, cover less than 10 percent of the semi-enclosed upper Rio.

Chesney and Iglesias (1979) found no remarkable differences in demersal fish biomasses in raft and non-raft areas, although diversity, species richness, and eveness indices were generally higher in the raft area. Reasons given for these results were that demersal fishes were unable to utilize the vast epifaunal resources associated with the raft because many of the kinds of epifaunal organisms were unsuitable as food. Likewise, the benthic infauna below the rafts was adversely affected by mussel feces and pseudofeces and thus presumably less infauna per unit area were available to demersal fishes than in non-raft areas.

Other forms of aquaculture not specifically mentioned by Odum (1974) which under some circumstances could be harmful to aquatic systems in which they are practised are cage and pen culture. Leopold and Bninska (1981) and Korycka and Zdawowsky (1981) call attention to the negative effects of cage culture in fresh waters in Poland. These include mineral and organic loading leading to eutrophication and attendant proliferation of algae, and permanent changes in the distribution of dissolved oxygen.

In contrast, it seems that by carefully matching the cage or pen culture "load" to the capacity of the system in which the cages or pens were installed, oligotrophic lagoons and estuaries might be made to produce more fish for capture purposes to the mutual benefit of both capture and culture fishery interests. There must be much information of use in the voluminous literature on the effects of pollution on aquatic systems which could be used as a frame of reference and a starting point for developing criteria to aid such matching.

The physical alteration of the environment to form fish enclosures, by constructing ponds, and by diking and closing off sections of lagoons may cause problems by limiting or changing circulation patterns, increasing sedimentation from dredging and filling, interfering with freshwater input, and by destruction of productive systems (marsh grass, mangroves, eel grass) adjacent to or within the estuary or lagoon. This latter problem could be particularly serious in the case of organisms which are estuarine dependent and for the fisheries existing for them, both within and outside the systems affected. The apparent dependence of shrimp yields on intertidal areas has been demonstrated for Indonesia by Martosubroto and Naamin (1977) and on a worldwide basis by Turner (1977) who points out the seriousness of loss of these areas through any means.

Odum (1974) suggests that one management solution would be to have the aquaculture facility release the equivalent amount of juveniles which would have been produced naturally if the estuary had

not been closed. However, he points out that the equivalent release may not imply the equivalent survival as achieved by natural stocks. This solution begs the issue, and not only that, is also impractical because aquaculture is likely to be based on only one or a few species of high economic value. Even if adequate numbers of these species were released they might not be the same species on which a lagoon, estuarine, or offshore fishery is based. Furthermore, the loss of space to other non-commercial fishes, invertebrates, and flora, which are important to maintaining the productive capacity of these waters should be considered.

Odum (1974) goes on to discuss the possible effects of artificial upwelling used for aquaculture (probably negligible, if for small projects) and the danger of accidental escapement into natural waters of exotic organisms used in fish culture. The latter problem can be quite serious, not only because of the adverse effects of the introduced organisms itself, but also due to any disease organisms which might be inadvertedly introduced with them. Finally, Odum (1974) draws attention to the possible proliferation of disease organisms and their introduction into natural waters due to the high density of the cultured animals which favours a greater incidence of disease than is usually normal in natural systems.

4.3.2 Other effects of aquaculture on capture fisheries

One possible adverse interaction of aquaculture with capture fisheries is the use and dependency of extensive brackishwater aquaculture on the collection of natural seed. In India, concerted research efforts have been made to determine the temporal and spatial distribution of shrimp larvae and of juvenile fishes in natural waters for use as seed to support culture operations (Shetty et al., 1971; Bhanot, 1971; Thakur, 1975, for example). In the Philippines extensive fisheries are based on the capture of Chanos fry for culture. There the by-catch, which may include the larvae of the valuable Penaeus monodon, is discarded. The extent to which seed gathering operations affect natural productivity and capture fisheries is unknown, but may require consideration and eventual management where seed collection is intensive until artificial reproductive techniques are perfected and the technology disseminated.

Another possible source of conflict is for space. This does not necessarily mean that the number of aquaculture installations would be so great as to physically crowd out capture fisheries altogether. Rather, if for example, extensive pen culture installations were placed on fishing grounds traditionally used by one family or a small cooperative, then the community's capture fishing allocational process could be upset. Direct interference with some capture fishing operations is another possibility, for example, the raft culture of mussels. Similarly, Owen (1981) remarks that the activities of net fishermen are severely restricted by oyster cultivation in many estuaries in South Wales (Australia). There, the problem is, in part, that some of the oyster leases are poorly managed and inadequately marked.

On the positive side there is the possibility that certain types of culture operations could beneficially interact with capture fisheries, much in the same way as has been suggested for traditional brush park "aquaculture" in Section 3.5. For example, pen culture installations could serve to attract wild fishes to their peripheries by providing shelter, for feeding on food items lost from inside the pen, and for feeding on fish food organisms associated with the pen itself. Ingestion by wild fishes of food items lost from the cage could reduce water quality problems engendered by the decomposition of unused food. Concentration of wild fishes in the vicinity of aquaculture installations could benefit capture fishermen by locally improving catch for effort expended. However, there is frequently mutual suspicion and antipathy between fishermen and fish culturists. A social and/or economic integration of these two activities is thus a prerequisite to the realization of any combined benefits.

Generally, in Australia decisions on the desirability of expansion of aquaculture in bays and estuaries are taken through consultations with many organizations and agencies to ensure a rational development of coastal resources. For example, in Tasmania leases are issued by the Lands Department but also participating in the issuance of leases are the Tasmanian Fisheries Development Authority, the Professional Fishermen's Association, and a number of other government agencies involved with health, navigation, environment, national parks and wildlife, as well as adjoing landowners, recreational boating organizations, and the public at large (Dix, 1981).

4.4 Interactions with Marine Nearshore and Offshore Fisheries

Competition between lagoon and estuarine fisheries and marine nearshore and offshore fisheries where the fishing is on the same or different life stages of the same species already exist for some shrimp species. For example, García (1978) has called attention to this problem with regard to Penaeus duorarum notalis lagoon/offshore fisheries in Ivory Coast, and García, Boely and Domain (1980) also treat the problem within the context of West African fisheries. Marcille (1978) mentions a similar shrimp fishery problem in Madagascar with P. indicus, and McGoodwin (1979) provides an overview of traditional versus marine shrimp fishery conflicts for the Pacific Coast of Mexico. Doubtless, there are instances of similar conflicts for finfishes. As lagoon and estuarine fisheries intensify, the incidence of such conflicts is bound to increase. Going the other way, one can imagine that with intensive effort exerted on nearshore and offshore stocks, estuarine and lagoon fisheries could be increasingly adversely affected in proportion to the extent to which they depend on the influx of species fished offshore or nearshore. For example, Jhingran and Natarajan (1973) have expressed concern that rapidly developing nearshore fisheries in the Bay of Bengal will adversely affect Chilka Lake (lagoon) finfishes.

The biological basis for such conflicts is the "estuarine dependence" of some organisms. That is, for some organisms passing a portion of their life cycles in estuarine or lagoon environments is obligatory for the completion of these life cycles. Most evidence exists for shrimps and prawns (Figs. 14 and 15). Other potential conflicts may have their biological basis in anadromous species, such as the Indian shad Hilsa ilisha, which pass through lagoons and estuaries on upstream spawning runs. Gopalakrishnan (1971) has drawn attention to this problem in that many of the most important species in the Hooghly-Matlah estuarine fishery are anadromous and are also fished to some extent in the Bay of Bengal marine fishery. Conflicts also may be based on marine species which are seasonal visitors to estuaries and lagoons purely for trophic purposes. One can also envisage potential adverse interactions between lagoon/estuarine and inland water fisheries for catadromous species such as Macrobrachium (Fig. 14).

Cases of lagoon/estuarine fishery interactions with marine fisheries which are quantifiable to the extent that management alternatives can be evaluated appear to be rare in the literature for tropical and sub-tropical regions. Lhomme (1979) has looked at the effect of artisanal estuarine Penaeus duorarum notalis fisheries on offshore fisheries for the same species in four West Africa estuaries, the Senegal, Sine Saloum, Gambia, and Casamance, but has found little evidence for negative interactions between estuarine and high-seas fisheries.

Garcia (1977 and 1978), however, has studied the problem in greater detail in connection with interactions between industrial offshore fisheries and lagoon fisheries for Penaeus duorarum notalis in Ivory Coast.

For practical purposes industrial offshore shrimp fishing for Penaeus duorarum notalis began in Ivory Coast in 1969. The main Ivorian fishing grounds cover about 1 000 $km^2$.

Migration of Penaeus duorarum notalis from lagoons and estuaries takes place at an age of 3 to 4 months after a period of 2.5 to 3 months in brackish waters. Migration peaks occur when rivers are in flood and lagoon/estuarine salinities are lowered. Size at migration can vary from one part of a lagoon to another, and among lagoons in the same year and among years in relation to salinity (García, 1977; García and Lhomme, 1980).

Ivory Coast has some 1 800 $km^2$ of coastal lagoons and mangroves which can serve as nursery areas for post-larval P. duorarum notalis. Lagoon shrimp fisheries are executed with closely grouped set nets fished on the ebbtide which fish the emigrating juveniles, and by a kind of scissor net which is pushed and effectively acts as a trawl. This latter gear fishes shrimp which have not as yet completed their growth in brackish waters. Artisanal shrimp fishing in lagoons generally gives higher income to fishermen than other kinds of fishing (García and Lhomme, 1980). In 1973, 55 percent by number of potential recruits to the marine fishery were captured by the lagoon artisanal fishery.

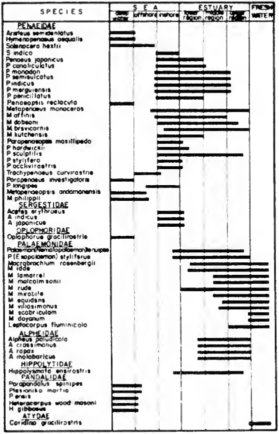


Fig. 14. Distribution in different environments of commercial prawns in India (from Mohamed and Rao, 1971)

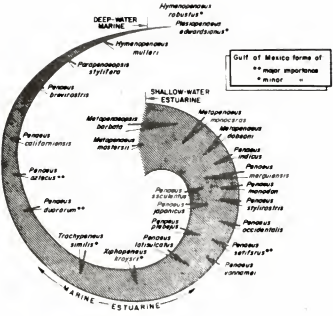


Fig. 15. Expected degree to which commercial penaeid shrimps inhabit estuarine environments during ontogenetic development (from Kutkuhn, 1966)

García (1978), using the available marine and lagoon yield data and other fishery parameters combined with biological data on P. duorarum notalis, has looked at artisanal lagoon/industrial fishery interactions through simulation of variations of exploitation rates in terms of offshore and lagoon yield, and relative value (Fig. 16).

Generalized results of this study indicate that variations in exploitation rates in lagoons (0-50 percent) would have only a slight effect on total yield (lagoon plus offshore) where the exploitation of the adults at sea is close to a MSY level but that the overall value of the catch could be increased from 12 to 40 percent by increases in industrial fishing at sea on the larger, higher-value individuals.

García (1978) noted that neither one nor the other of extreme resource management measures would be viable -- elimination of the lagoon artisanal fishery, or elimination of industrial fishery. Elimination of the lagoon fishery would, of course, cause socio-economic, not to mention, political havoc. Suppression of the marine industrial fishery with all future effort concentrated in lagoons could lead, at least, to the economic, if not biological extinction of the species through lagoon overfishing, if a minimum abundance of spawning stock was not maintained. García (1978) proposes four general lagoon fishery management measures which would help to ensure increased recruitment of shrimp to the offshore industrial fishery: (1) control of mesh sizes of fixed fishing gears (set nets); (2) strict limitation or prohibition of the gears which fish juvenile shrimp before their migration; (3) regulation on the locations of nets set on shrimp emigration routes in channels; and (4) a closed season both at sea and in lagoons at the time of peak migration towards lagoons and during the period of maximum post-larval growth.

Artisanal/industrial shrimp fishery interactions have been looked at by Marcille (1978) on the northwest coast of Madagascar. Artisanal fisheries there are executed with barrage traps of natural woods set in a V-shape in tidal waters in, or near river mouths which are adjacent to the nursery areas of the shrimp, mostly P. indicus. As a result of their location and because of the characteristics of the trap itself, many shrimps of less than commercial size are caught. The use of such traps has increased in recent years in the Baie d'Ambaro area due to the stimulus of the formation of shrimp export companies which send refrigerated trucks to the coastal villages to collect the catch. Beach seines are also used to some extent.

Using data and analytical techniques much like those employed by García (1977) (above), Marcille (1978) was able to show that suppression of artisanal fishing in the Baie d'Ambaro could increase the catch of the industrial fishery from 8 to 30 percent, based on differing assumptions of natural mortality rates, with consequent shrimp size-related increases in profits of 15-45 percent.

Among the artisanal fishery management options which were entertained by Marcille (1978) were: (1) closed areas; (2) a closed season with closure to begin after a certain yield had been obtained; (3) closed season by fixed time period; and (4) protection of young shrimps. The first three management options were rejected as unworkable because of the inability to identify various nursery areas for various species (three species are included in the offshore fishery) with grounds where they are fished and because of differing timing in life history stages among stocks and therefore differing temporal availability.

Control of the selectivity of the barrage traps was believed to be a viable management option. Data indicated that the mean distance between the "meshes" of the trap was only 7.5 mm and should be increased to about 11 mm, which could be easily accomplished by modifying the materials used. Adoption of such a regulation would benefit the barrage fishermen in tnat the average size of shrimp in the catch would increase as would their value per unit while at the same time increasing recruitment to the industrial fishery. Limitation of the number of barrages in use was not considered advisable because the barrage traps also catch finfish which are important to the villages. However, a gradual change-over to beach seines was advocated on the basis that their mesh sizes could be more easily controlled than those of the barrage traps.

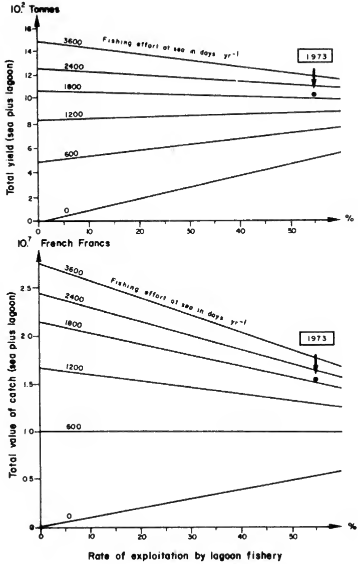


Fig. 16. The effect of rate of exploitation by lagoon artisanal fisheries and effort exerted by marine industrial shrimp fisheries on total yield and total value of the shrimp fishery in Ivory Coast. Actual situation in 1973 and other simulated situations (from García, 1978)

## 5. SUMMARY AND CONCLUSIONS ON THE MANAGEMENT OF COASTAL LAGOON AND ESTUARINE FISHERIES

The general thrust of the first part of this chapter has been to call attention to a variety of lagoon fishery management problems and to present a number of regulatory and non-regulatory fishery management options as possible solutions to these problems.

With regard to various forms of regulatory management, it has been seen that for a number of socio-economic and political reasons, and because of technical and financial constraints, "comprehensive" and stringent regulation of the coastal lagoon and estuarine fisheries of most developing countries is not possible at this time. However, management through the regulation or elimination of the most destructive fishing practices is within the financial, administrative, and technical reach of many countries. Revitalization and reinforcement of traditional fishery management practices appears to offer an attractive means to supplement or complement fishery regulation by central government intervention.

Attention was also drawn to non-regulatory lagoon and estuarine fishery management techniques which were directly or indirectly aimed at increasing biological production and fishery yield through various kinds of biological manipulations -- predator control, artificial spawning areas, hydraulic management, and brush-park fisheries. Among the most potent of these techniques would appear to be hydraulic management for fisheries; however, wide acceptance and utilization of the techniques available will depend on local/national economic situations and the extent to which hydraulic management for fisheries can be shown to incorporate benefits for other users of lagoons and adjacent terrestrial environments. The brush-park fisheries method also holds out good possibilities for enhancing the management of lagoon and estuarine fisheries. In addition to the advantage of high yield relative to open-water capture fisheries, brush-park fisheries are labour intensive and do not carry the threat of unemployment or underemployment which could be caused by adoption of more sophisticated aquaculture techniques. Further, brush parks do not represent a radical technological departure from capture fishing in terms of construction and operation as do some forms of aquaculture. Thus, a gradual change-over of some parts of lagoons and estuaries to brush-park fisheries would be more akin to the step-by-step process of technological change advocated by Lawson (1977) than would be the introduction of other fish culture techniques requiring higher-level technological training backed up by readily available technical assistance through extension services and applied research facilities which may financially strain developing countries.

The intent in the second portion of the chapter -- conflicts and interactions -- was to bring to light two basic ideas. The first is that management of fisheries such as exist in lagoons and estuaries of many developing countries depends as much, or more so, on an understanding of the socio-economic ramifications of the fisheries as it does on biological knowledge of the resources and capture characteristics of the fishery. In short, too often the fishery manager with a biological background observes and treats the symptoms (overfishing, destructive fishing practices) while the "disease" is really imbeded in the socio-economic framework of the local fishing community or in the national economy.

The second basic idea is that lagoon and estuarine capture fisheries cannot be managed as single or isolated entities, but rather are biologically and economically integrated with marine nearshore and offshore fisheries, with rapidly developing aquaculture, and to some extent with freshwater riverine fisheries. In this situation, too, management is not only a matter of biology and population dynamics, but also a matter of national economic and sociological development objectives and priorities.

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